

NASA-TM-84395 19840005110

Preliminary Results of the First Static Calibration of the RSRA Helicopter Active-Isolator Rotor Balance System

C. W. Acree, Jr.

November 1983

LIBRARY COPY

JAN 3 1984

LANGLEY RESEARCH CENTER
LIBRARY, NASA
HAMPTON, VIRGINIA



National Aeronautics and
Space Administration

Preliminary Results of the First Static Calibration of the RSRA Helicopter Active-Isolator Rotor Balance System

C. W. Acree, Jr., Ames Research Center, Moffett Field, California



National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035

N84-13178 #

SUMMARY

The helicopter version of the Rotor Systems Research Aircraft is designed to make simultaneous measurements of all rotor forces and moments in flight in a manner analogous to a wind-tunnel balance. Loads are measured by a combination of load cells, strain gages, and hydropneumatic active isolators which use pressure gages to measure loads. A complete evaluation of system performance requires calibration of the rotor force- and moment-measuring system when installed in the aircraft. Measurement system responses to rotor loads obtained during the first static calibration of the helicopter are plotted and discussed here. Extensive plots of the raw transducer data are included in the appendix.

INTRODUCTION

A major goal of the Rotor Systems Research Aircraft (RSRA) is measurement of the forces and moments generated by a helicopter rotor in flight. Each of the two RSRA's has a different system for measuring rotor loads as described in reference 1. The first static loads calibration of the compound RSRA is discussed in reference 2; the first calibration of the helicopter version of the RSRA with the active isolator system is described in this paper. Raw transducer outputs were transformed to a consistent set of rotor loads axes to provide the system response plots presented here. The appendix provides a wide selection of untransformed raw data.

Description of Aircraft Systems

Figure 1 shows the basic concept of RSRA rotor loads measurement, whereby rotor loads are transmitted from the base of the transmission, to the airframe, through a collection of force transducers. The system used on the RSRA helicopter is shown in more detail in figure 2. Four load cells in a focused arrangement measure vertical loads and allow in-plane loads to be taken up by four active isolators. In addition, a torque link (partly hidden in the figure) relieves the isolators of part of the static torque loads and provides structural redundancy for safety. The torque link has conventional strain gages for load measurement. The entire system functions analogously to a wind-tunnel balance.

The active isolators are described in detail in reference 3. Figure 3 schematically shows the features of interest. The pneumatic springs absorb vibratory loads, while the servo valve keeps the piston centered under large steady loads. A differential pressure transducer provides load data. Since

there are internal friction losses within the isolators, it is preferred not to convert pressure data directly to force data as this would slightly reduce the accuracy. A piston lock provides a separate load path for safety in the event of isolator or hydraulic system failure. It also provides a convenient zero reference for optional displacement transducers (not shown).

Calibration Requirements

It is desired that rotor forces and moments be measured with accuracies traceable to the National Bureau of Standards. Individual component calibrations are insufficient, because structural flexibility in the airframe changes the load distribution among the transducers, causing interactions (cross-talk) and changes in effective sensitivities. Moreover, the isolator pistons must move slightly to absorb vibration, and any motion under static loads will further change the load distribution. Isolator internal friction and accumulated rigging (alignment) errors accentuate the problem. Therefore, the entire load measurement system must be calibrated when installed in the aircraft.

Figure 4 illustrates the static calibration method. A special calibration fixture replaced the rotor head, and the airframe was restrained by the landing gear mounting lugs. Hydraulic cylinders applied static loads through cables and pulleys, except for lift where a solid rod and walking beam were used. High-accuracy calibration-reference load cells connected the cables and rod to the rotor head fixture. Weight was not important here, so the calibration fixture components were designed for high stiffness, and their geometry was arranged to allow the reference load cells to directly measure applied loads with maximum accuracy.

Figure 5 shows the calibration-reference axis system. Table 1 shows the values of the calibration loads. The single loads represent the performance limits of the RSRA's S-61

TABLE 1.— CALIBRATION FACILITY LOAD APPLICATION CAPABILITIES (1983)

Axis	Positive direction	Single load limit (100%)	Combination load limit	Applied load accuracy
X = longitudinal	Forward	±8,620 lb	±4,000 lb	17 lb, 0.2% full-scale
Y = lateral	Right	±5,420 lb	±2,500 lb	14 lb, 0.3% full-scale
Z = vertical	Down	-48,800 lb	-24,400 lb	68 lb, 0.2% full-scale
L = roll	Right down	±16,667 ft-lb	±8,333 ft-lb	58 ft-lb, 0.4% full-scale
M = pitch	Nose up	+25,500 ft-lb -16,667 ft-lb	+12,500 ft-lb -12,500 ft-lb	67 ft-lb, 0.3% full-scale
N = torque	Left forward	+58,167 ft-lb	+50,000 ft-lb	31 ft-lb, 0.06% full-scale

rotor, while loads in combination are reduced because of structural limitations of the airframe. The most important combined loads are those with lift (Z) and torque (N) because these two loads are significant for virtually all reasonable flight conditions. The combination load limits have been slightly modified as compared with those used in the first calibration (ref. 2), and significantly expanded in the torque (N) axis.

The reference load cells were individually calibrated with equipment traceable to the National Bureau of Standards. Such calibrations of the reference load cells determined the facility accuracies given in table 1. The listed values are the standard deviations of the errors in measuring each applied load, and have been rounded to be conservative.

All calibration data were taken by a high-accuracy digital voltmeter connected to a high-speed data scanner. A small computer converted raw voltage readings to engineering units, displayed selected parameters in real-time, and stored all of the data on floppy disks. The data were later transferred to a large main-frame computer for editing, plotting, and analyzing.

COMPARISON OF PREDICTED AND APPLIED LOADS

Interpretation of the results may be simplified by comparing predicted loads to the known applied loads. This requires a calibration matrix to transform raw transducer outputs to resultant loads in the same coordinate system used for calibration (fig. 5). The analysis required to calculate the optimum calibration matrix is discussed in reference 2. For present purposes a simple matrix derived from system geometry will suffice. If the airframe had no manufacturing, assembly, or rigging errors and was perfectly rigid, the geometric matrix used here would be optimal.

The results of converting the data with the geometric matrix are plotted as predicted loads against known applied loads in figures 6-11. Only single loads (case 1 in the appendix) are plotted. For these plots, all loads were normalized with respect to the maximum loads in each axis. All six

predicted loads could therefore be shown on the same plot for each applied load, allowing direct comparison of relative accuracies. A perfect prediction in the same axis as the applied load would be a diagonal line with a slope of unity (the dashed reference line). Perfect predictions in all other axes would be exactly zero.

The main rotor shaft of the RSRA is inclined two degrees forward with respect to the airframe. To simplify calibration, the aircraft was attached to the calibration facility framework in a 2° nose-up attitude, thereby orienting the main rotor shaft exactly vertically. This ensured that the weights of the transmission and the rotor head calibration fixture caused only constant bias errors in the calibration-reference axis system. In normal flight conditions, there is a large constant torque load, so the two lateral isolators are preloaded in order that they will operate near the middle of their measurement range. These isolator preloads introduced more bias errors during calibration.

A full calibration analysis would determine the best corrections for these bias errors, but the geometric matrix cannot correct for all such errors. To simplify the data plots given in figures 6-11, the data were empirically adjusted to give zero total mean errors for all single loads. The plots thus reveal slope errors, relative local bias errors, asymmetry, non-repeatability, hysteresis, and other nonlinearities.

Standard deviations of the errors in predicting loads with the geometric matrix are given in table 2. Bias errors were

TABLE 2.— LOAD PREDICTION ERRORS^a

Axis	Full scale limit	Error standard deviation	
X	8,620 lb	317 lb,	3.7% full-scale
Y	5,420 lb	229 lb,	4.2% full-scale
Z	48,800 lb	102 lb,	0.2% full-scale
L	16,667 ft-lb	970 ft-lb,	5.8% full-scale
M	25,000 ft-lb	1104 ft-lb,	4.4% full-scale
N	58,167 ft-lb	3207 ft-lb,	5.5% full-scale

^aErrors are based on a geometric conversion matrix. Bias errors are not included.

removed before calculating the standard deviations. The statistics, therefore, correspond exactly to the data as shown in figures 6-11.

DISCUSSION OF RESULTS

Considering for the moment only primary responses to single-axis applied loads, the *Z* axis has the best accuracy (table 2). Figure 8 shows that the behavior of the *Z*-axis measurements is very close to the ideal, nearly matching the limiting accuracy of the calibration facility (table 1).

Figures 6 and 11 show the *X*-axis errors are slightly affected by linear slope errors, and the *N*-axis errors are strongly affected. Note that even a small slope error could cause a significant error at the extremes of the measurement range. These slope errors are theoretically correctable by a linear analysis. However, the *N*-axis would still show residual nonlinearity, and the *X*-axis would certainly have residual hysteresis errors.

Both *Y*- and *L*-axis errors are clearly dominated by erratic hysteresis, as shown by figures 7 and 9. There is also a slight slope error apparent in the *L*-axis. Only a slight reduction in error for either of these two axes could be expected to result from a more sophisticated analysis.

The major source of error in the *M*-axis is nonrepeatability (fig. 10). It cannot be determined from the data presented here whether this is a recurring problem with the load measurement system, or a result of a partial failure of calibration facility equipment. The latter case is suspected, but a more detailed analysis is required to confirm this hypothesis. If it is true, then a recalibration would reveal much lower *M*-axis errors.

There are 30 different cross-axis responses shown in figures 6-11. They are covered only very briefly here, taking each applied load in turn. Applied *X*-loads cause slight linear slope errors in *L* and *M*, and mostly a local bias error in *Y*. Applied *Y*-loads cause large erratic hysteresis errors in *L*, but negligible other cross-axis errors. *Z*-loads cause considerable local bias and slope errors in all other axes, plus very erratic hysteresis in *Y* and *L*. Applied *L*-loads have an effect on *Y* similar to that of applied *Y*-loads, but it is reduced in magnitude. Applied *M*- and *N*-loads cause very slight slope errors in nearly all other axes. Also, *N*-loads cause erratic responses in *Y* and *L*.

CONCLUSIONS

The major types of error in the active isolator version of the RSRA loads-measurement system are biases and linear slope errors. These are theoretically correctable by proper data processing, so a full calibration analysis appears to be worthwhile. The *Y*- and *L*-axes (side-force and roll) are expected to show the largest residual measurement errors, which are mostly due to hysteresis. The *Z*-axis (lift) shows by far the lowest error.

The *M*-axis (pitch) shows significant nonrepeatability which is thought to be due to improper performance of the calibration equipment; however, this has yet to be conclusively proven. This qualification aside, the calibration revealed nothing which would prevent the active-isolator loads-measurement system from providing usable flight research data.

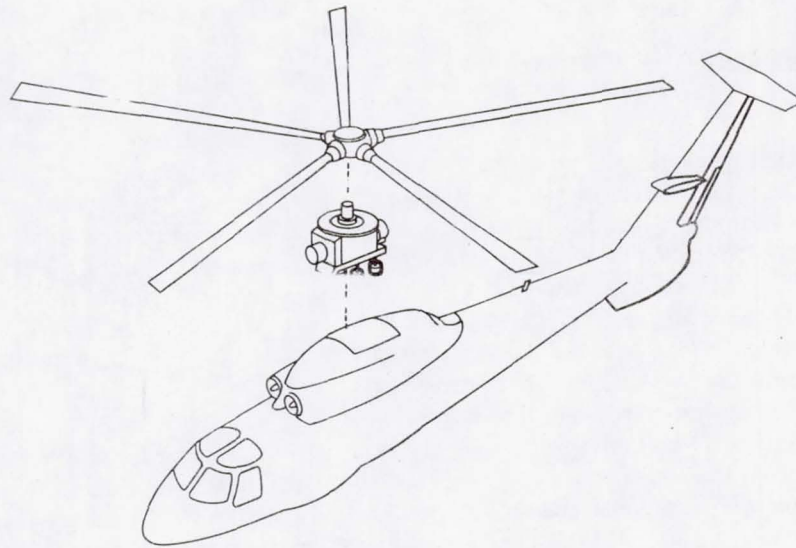


Figure 1.— RSRA helicopter force- and moment-measurement systems.

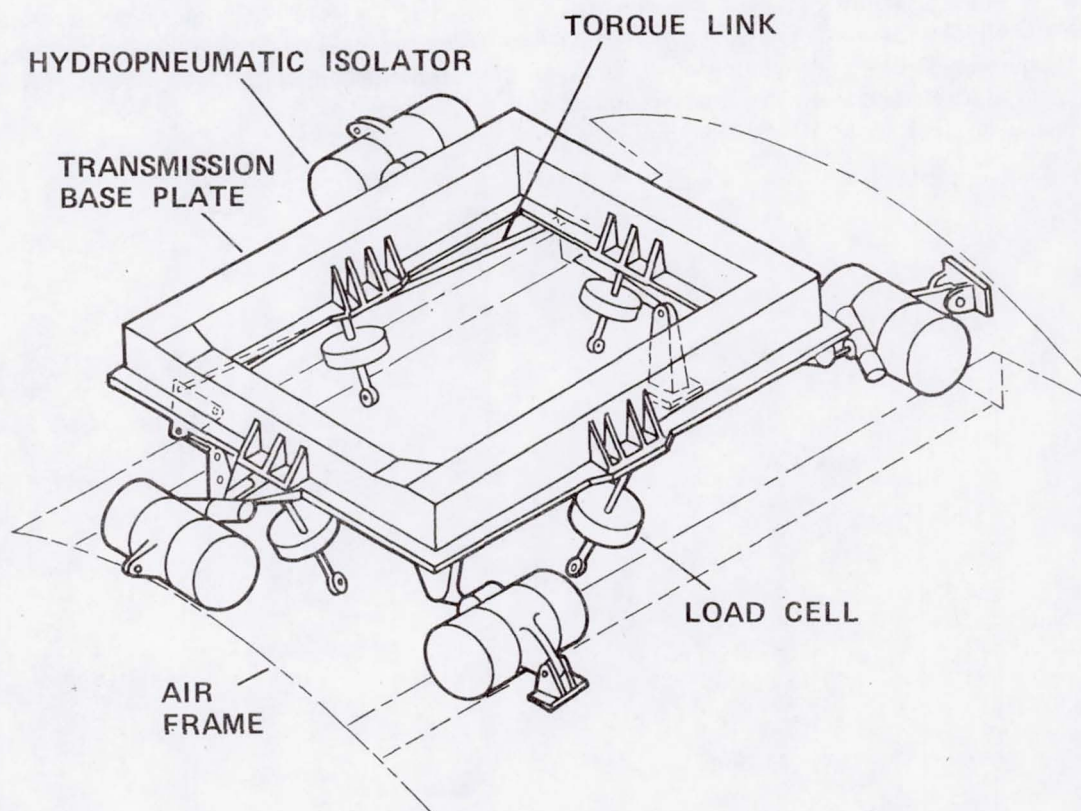


Figure 2.— Rotor force- and moment-measurement system: active isolation and balance system configuration.

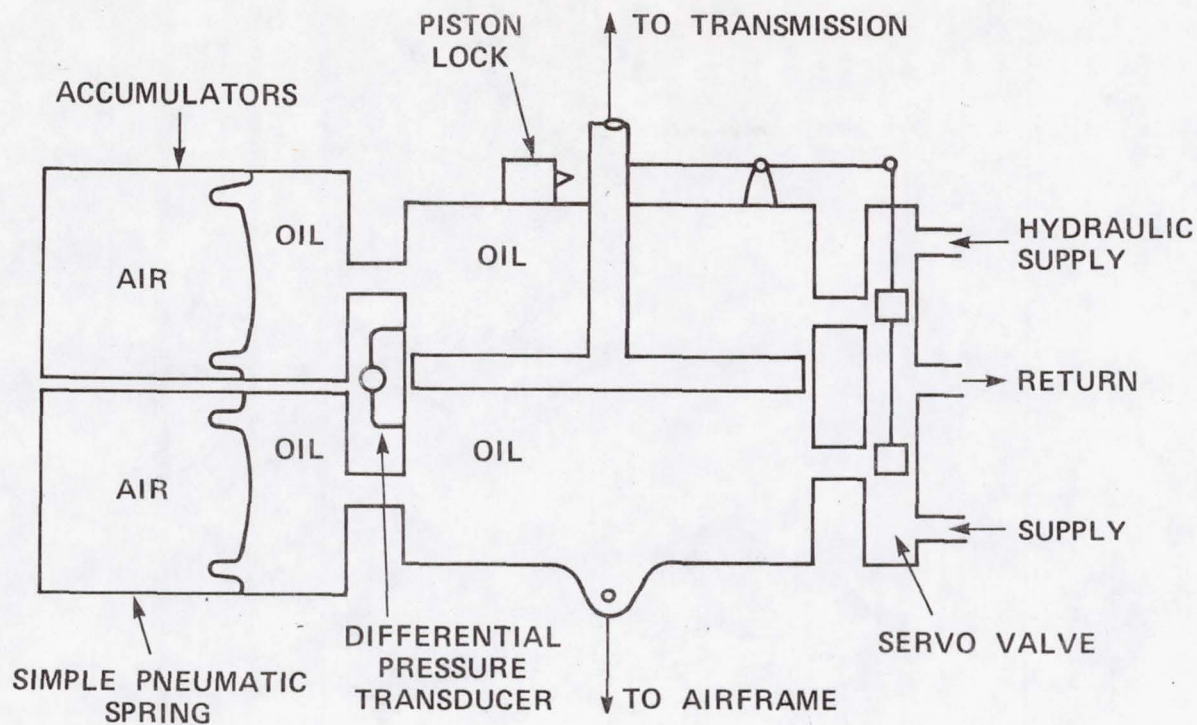


Figure 3.— Schematic of hydropneumatic active isolator.

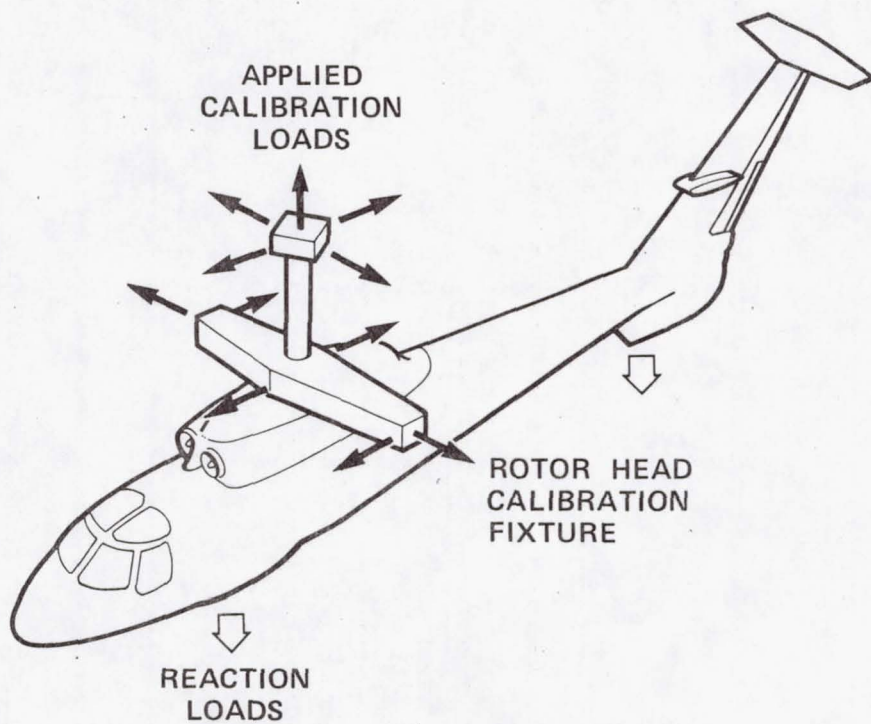


Figure 4.— Method of applying static rotor calibration loads to the RSRA.

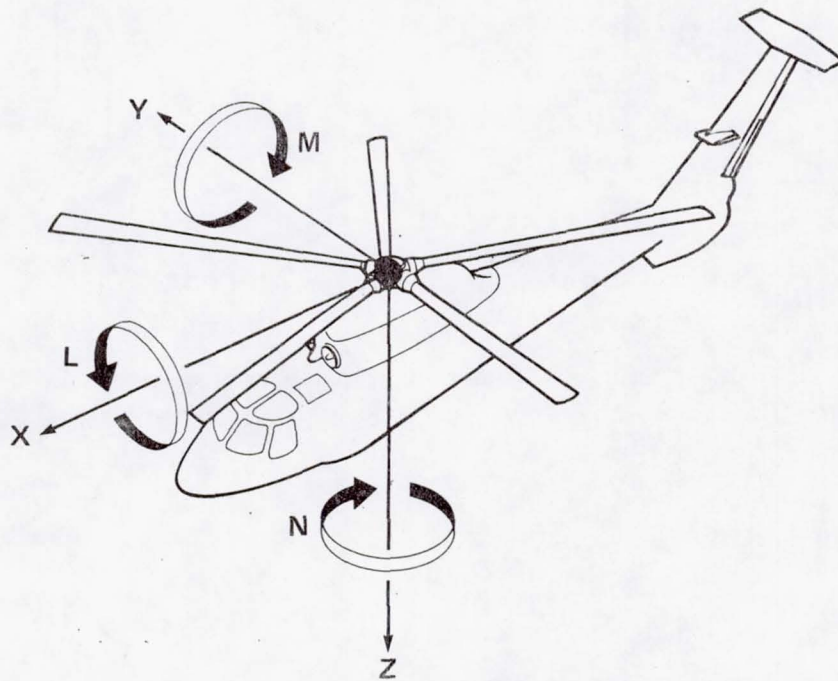


Figure 5.— RSRA rotor calibration axis system.

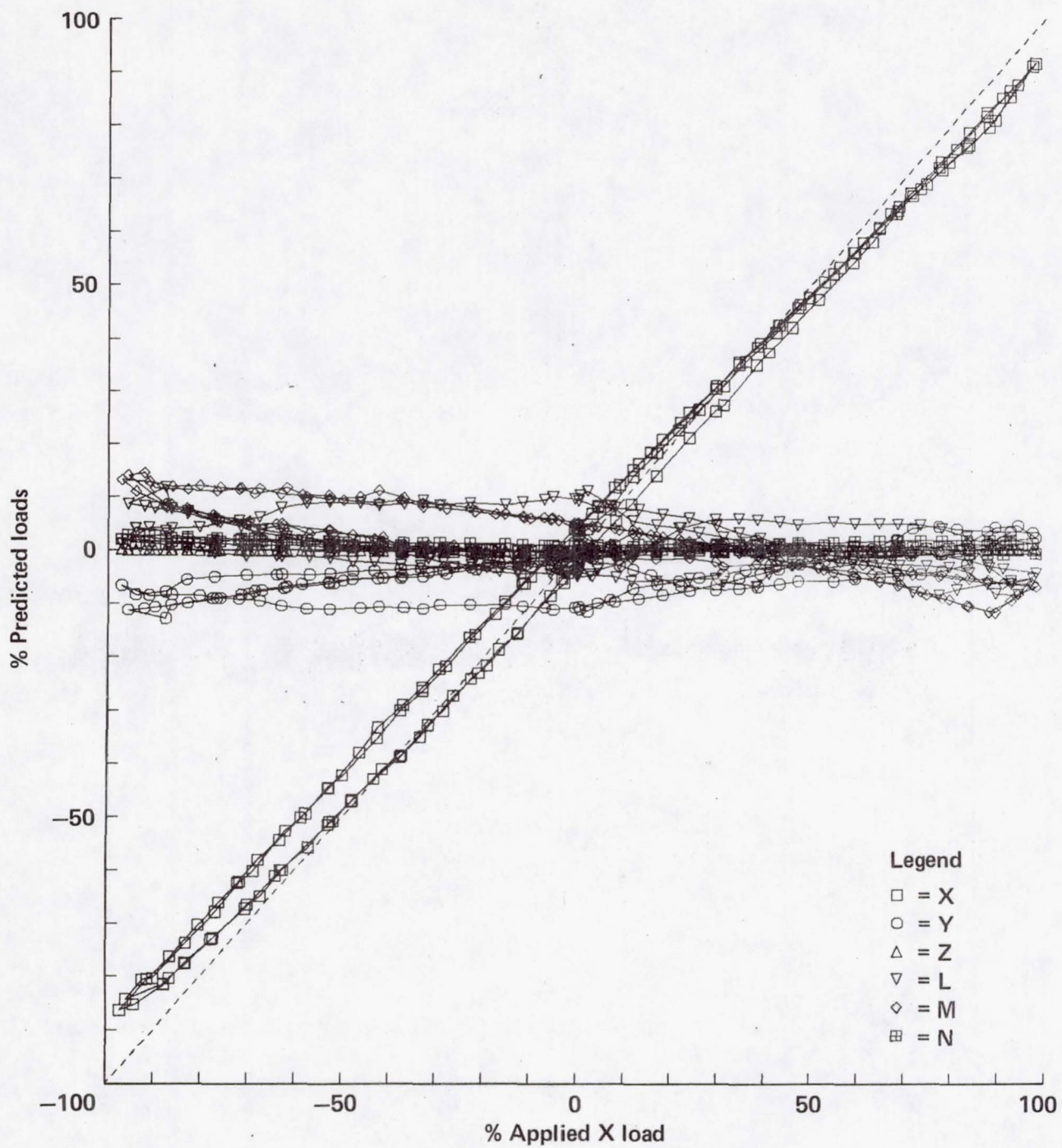


Figure 6.— Predicted loads vs applied X load.

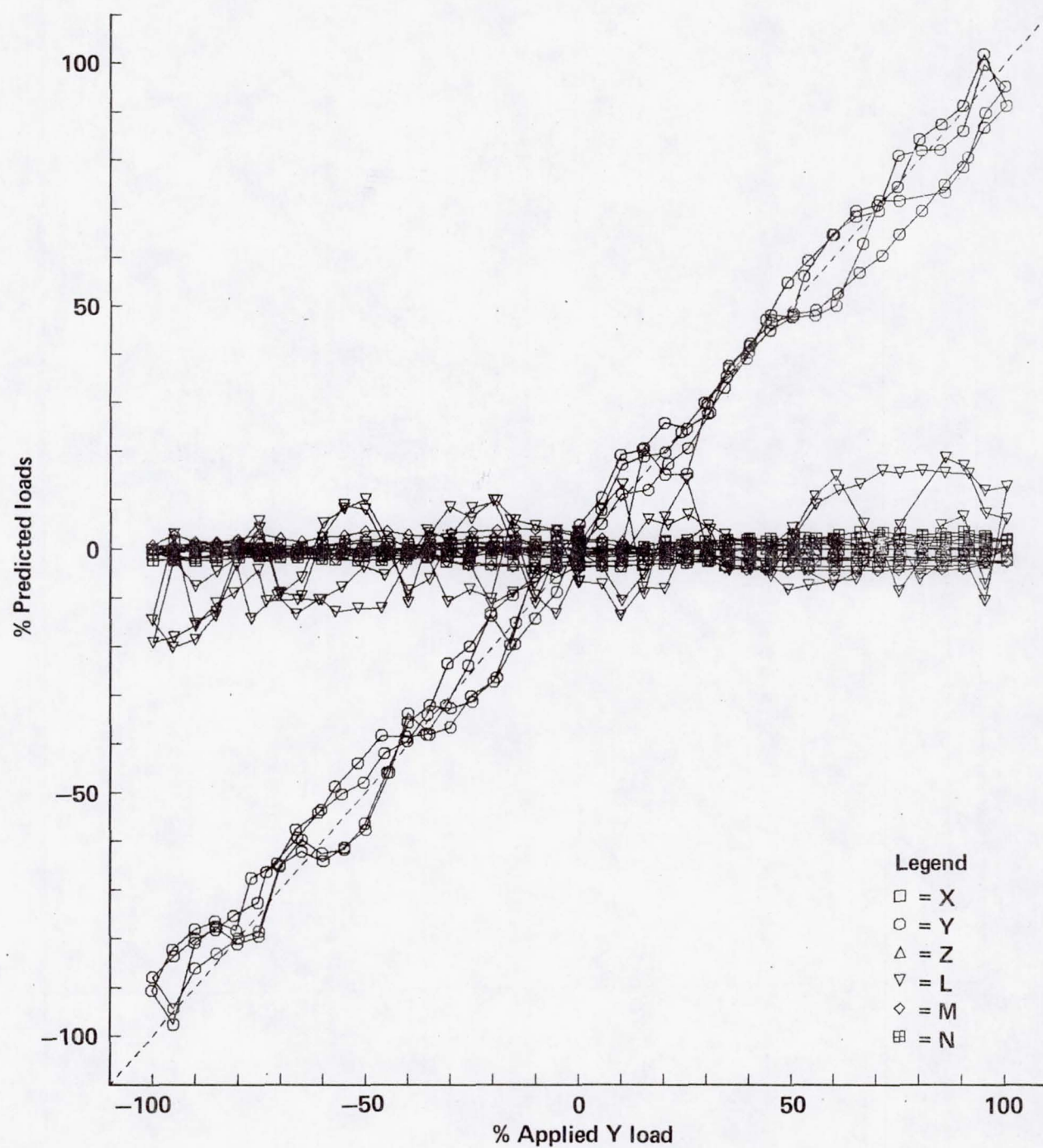


Figure 7.— Predicted loads vs applied Y load.

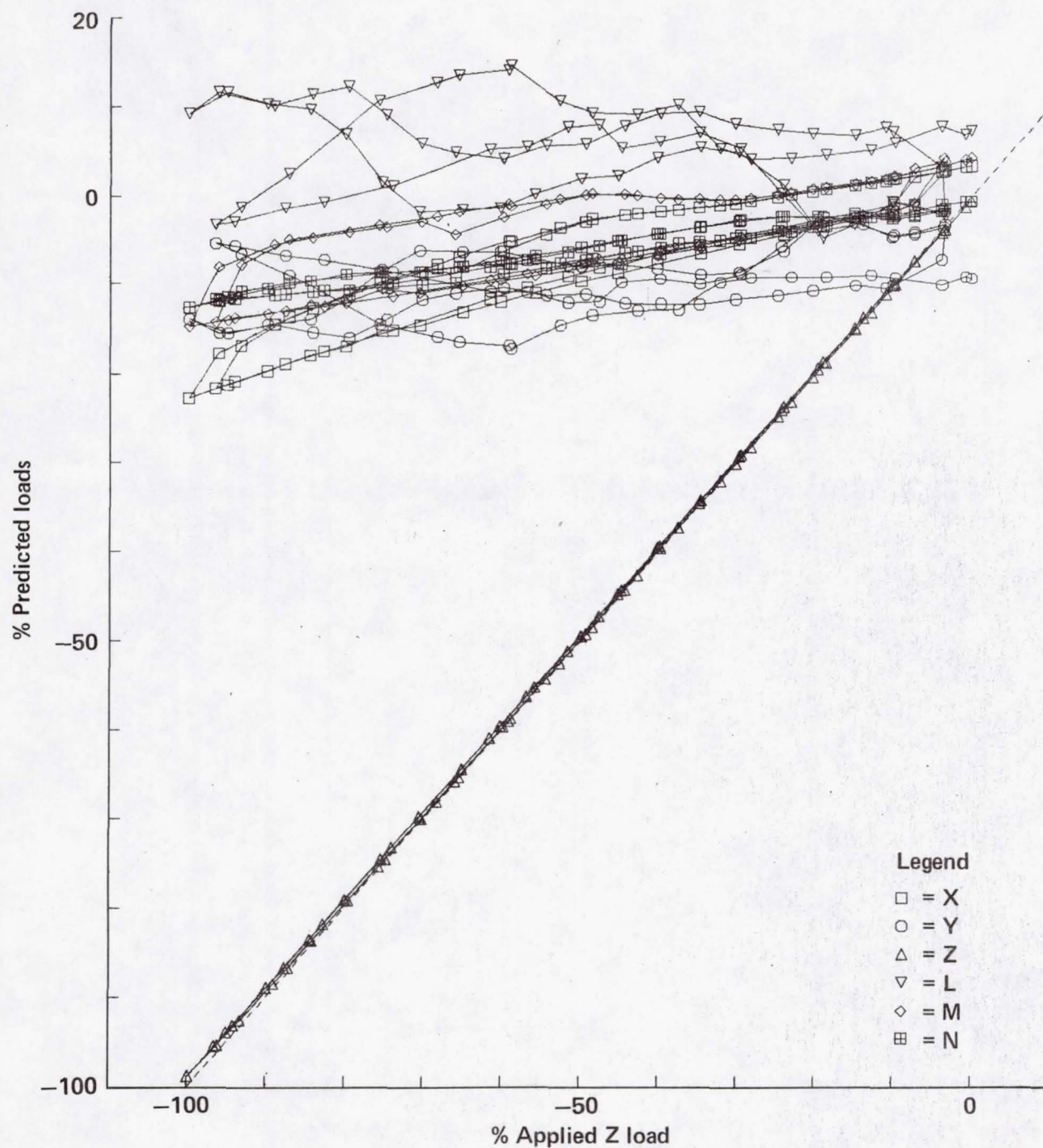


Figure 8.— Predicted loads vs applied Z load.

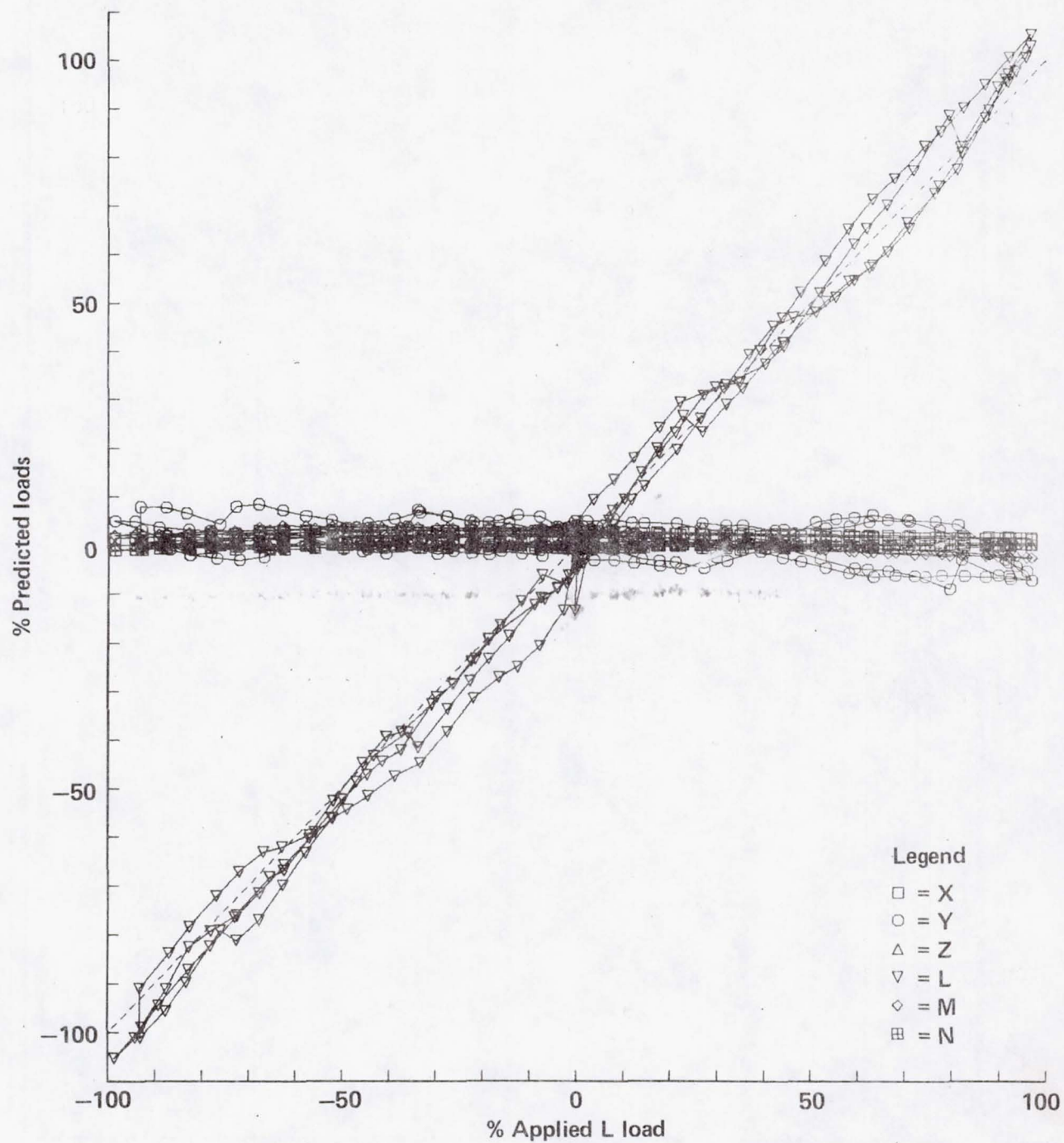


Figure 9.— Predicted loads vs applied L load.

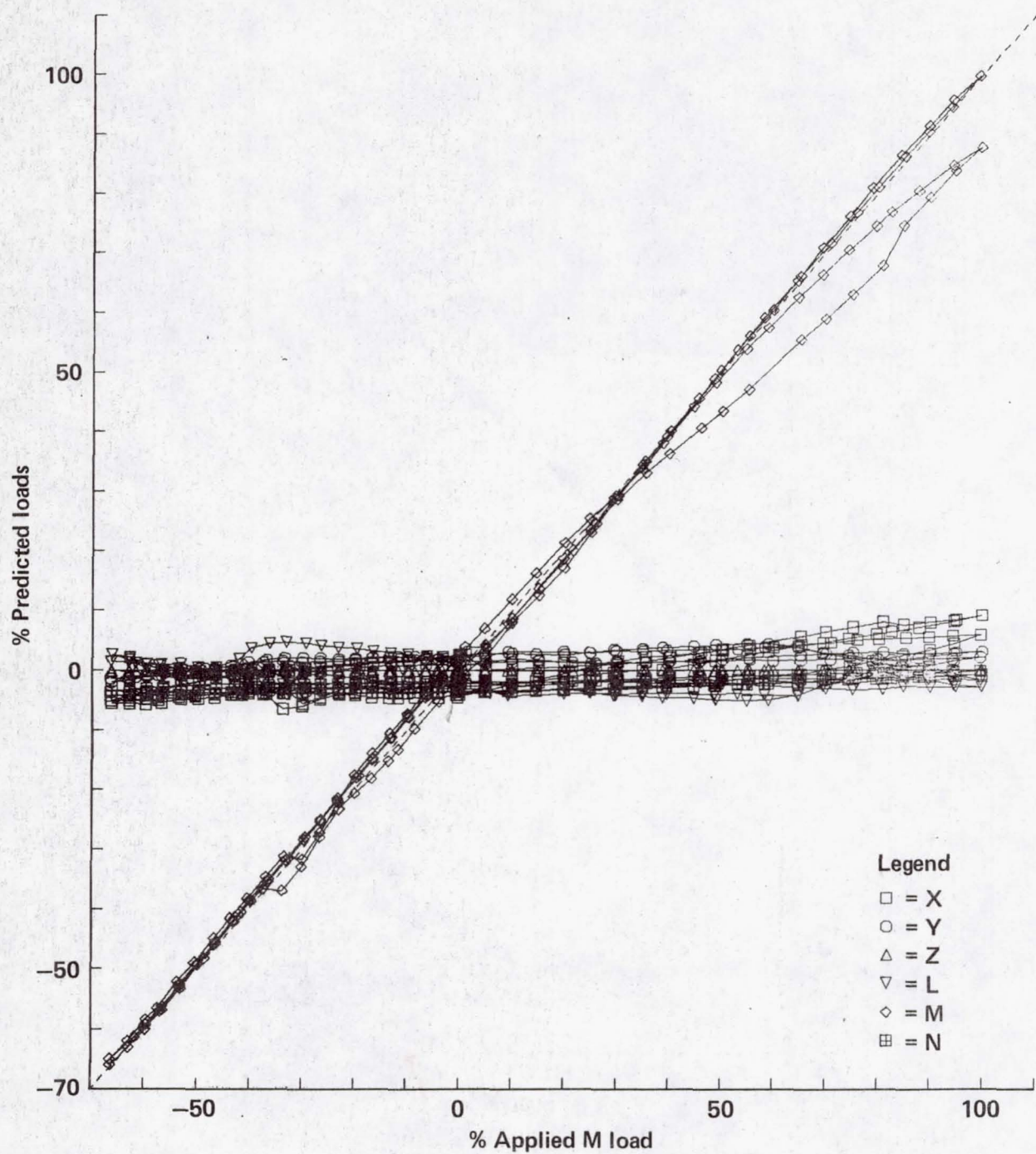


Figure 10.— Predicted loads vs applied M load.

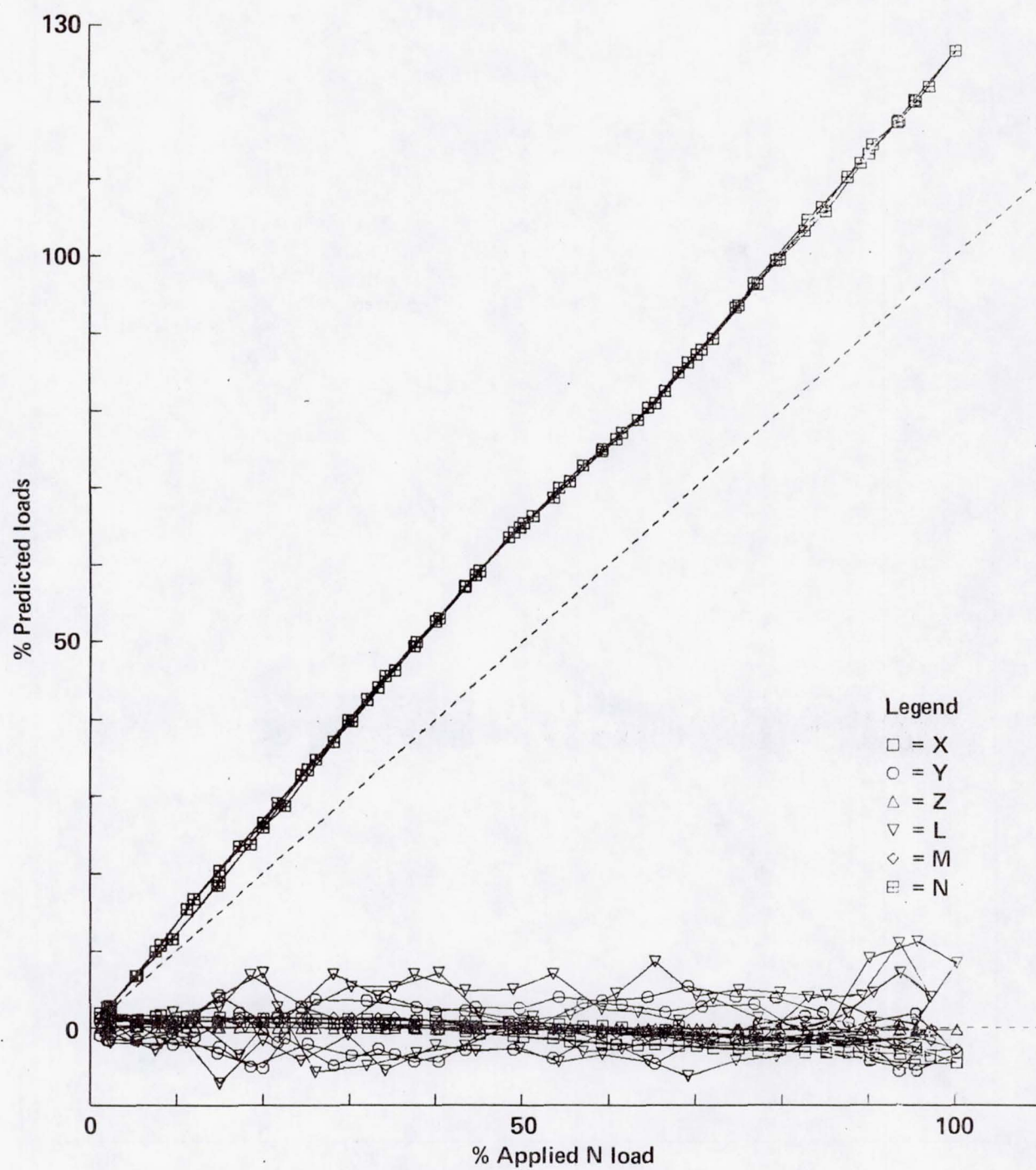


Figure 11.— Predicted loads vs applied N load.

APPENDIX

RAW DATA PLOTS

A collection of selected plots including most of the raw data comprises this appendix. Each plot shows an aircraft transducer — load cell, pressure gage, etc. — plotted against applied load. The horizontal scales are fixed to match the maximum applied load, but the vertical scales are allowed to vary so that the data curves will fill the page, better revealing detail. Table A1 shows the maximum (full-scale) magnitudes of each transducer output. Allowable full-scale applied load values were provided in table 1 of the main text.

Most transducer data have been converted into engineering units of force (pounds) or displacement (inches). Isolator data are plotted as differential pressure (psi). Isolator data may be converted into approximate units of force (neglecting isolator internal friction) by multiplying by the isolator piston area, 17.32 in.². This is only a scaling change and will not alter the shape of the data curves, but is not as accurate as units of pressure because the isolators have not been individually calibrated to determine internal losses. Isolator displacement data have been corrected to give zero readings at the "locked-out" positions of the isolators. Main rotor shaft torque strain gage data have been left in output voltage units.

Table A2 lists all cases of load combinations for which plots are included. To save space, several runs are plotted

together for each varied load included in each case. There are 15 transducer plots for each varied load axis under each case, for a total of 240 plots.

Each case includes a different series of constant loads in the Z- and N-axes, with varied loads in other axes. A constant load of zero means only that there was no load held at a fixed nonzero value; varied loads in that axis were still allowed. Constant loads were applied only in the Z- and N-axes because these are the two axes that in straight-and-level flight or hover would experience large constant load components in addition to relatively small trim and vibratory loads.

Case 1 is the simplest case, with loads applied in only one axis at a time (single loads). Two complete replications over the full-scale range are shown in each plot, in the same order as the loads were applied: positive, negative, positive, negative. Z and N are one-sided axes, so only two data runs are plotted for them, negative or positive as appropriate. The first data run plotted was preceded by an identical run (not shown) that exercised the measurement system to give more consistent measurements of hysteresis in that axis. The first run plotted therefore shows the effects of prior exercising in the same direction for that axis, while the second and

TABLE A1.— MAXIMUM RANGES OF AIRCRAFT TRANSDUCER OUTPUTS

Transducer	Minimum	Maximum	Full scale
Forward load cell, lb	-11,000	16,000	±25,000
Right load cell, lb	-9,000	11,000	±25,000
Left load cell, lb	-9,000	9,500	±25,000
Aft load cell, lb	-9,000	10,000	±25,000
Torque link, lb	-10	175	N/A
Left isolator pressure, psid	-75	850	±3,000
Right isolator pressure, psid	-100	850	±3,000
Forward isolator pressure, psid	-750	750	±3,000
Aft isolator pressure, psid	-1	18	±3,000
Left isolator displacement, in.	-0.0205	-0.001	±0.40
Right isolator displacement, in.	0.014	-0.035	±0.40
Forward isolator displacement, in.	0.015	0.0315	±0.40
Aft isolator displacement, in.	-0.32	0.0	±0.40
Shaft torque gage MRQ1, volts	-0.0210	0.0052	N/A
Shaft torque gage MRQ2, volts	0.00085	0.0240	N/A

TABLE A2.—LOAD COMBINATIONS

Case	Constant loads		X	Y	Varied loads		M	N
	Z, %	N, %			Z	L		
1	0	0	55-58	61-64	52-53	72-75	82-85	67-68
2	0	85	120-121	99-100	(34)	118-119	101-102	N/A
	25	85	47-48	93-94	N/A	107-108	103-104	N/A
	50	85	41-42	39-40	N/A	35-36	37-38	N/A
3	50	0	79-80	97-98	N/A	116-117	<i>a</i>	(33)
	50	40	49-50	95-96	N/A	109-110	<i>a</i>	N/A
	50	85	41-42	39-40	N/A	35-36	37-38	N/A
4	0	0	---	---	---	---	---	68
	25	0	---	---	---	---	---	43
	50	0	---	---	---	---	---	33
5	0	0	---	---	53	---	---	---
	0	40	---	---	44	---	---	---
	0	85	---	---	34	---	---	---

^aUnreliable data not included.

subsequent runs plotted show the effects of exercising in the opposite direction (except for Z and N).

Cases 2 and 3 show the differences in transducer response when one constant-load axis is held fixed while the other is stepped through different constant load levels. This allows comparisons to be made of the effects of different flight conditions, with a zero reference. Note that some data runs are

included in both cases. These runs represent the maximum allowable values of multiple constant loads.

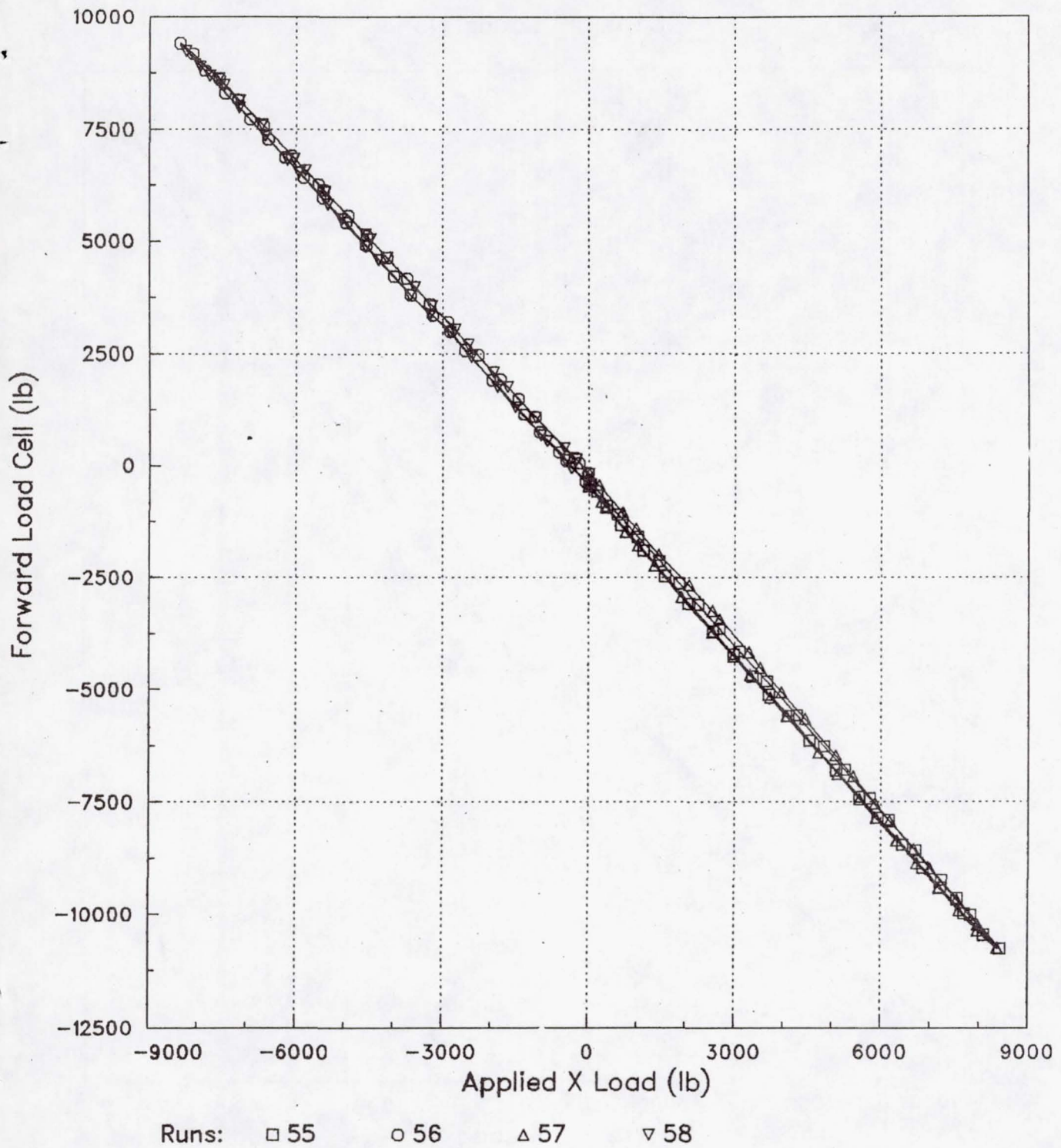
Since a load cannot be held constant and varied at the same time, the effects of different constant loads on the Z- and N-axes are shown separately in cases 4 and 5. Case 4 is a variation of case 2, with N varied instead of held constant, and case 5 is a variation of case 3, with Z varied instead of held constant.

LIST OF APPENDIX FIGURES

Case	Varied Load	Page
1	X	17
	Y	32
	Z	47
	L	62
	M	77
	N	92
2	Y	107
	Y	122
	L	137
	M	152
3	X	167
	Y	182
	L	197
	M	212
4	N	227
5	Z	242

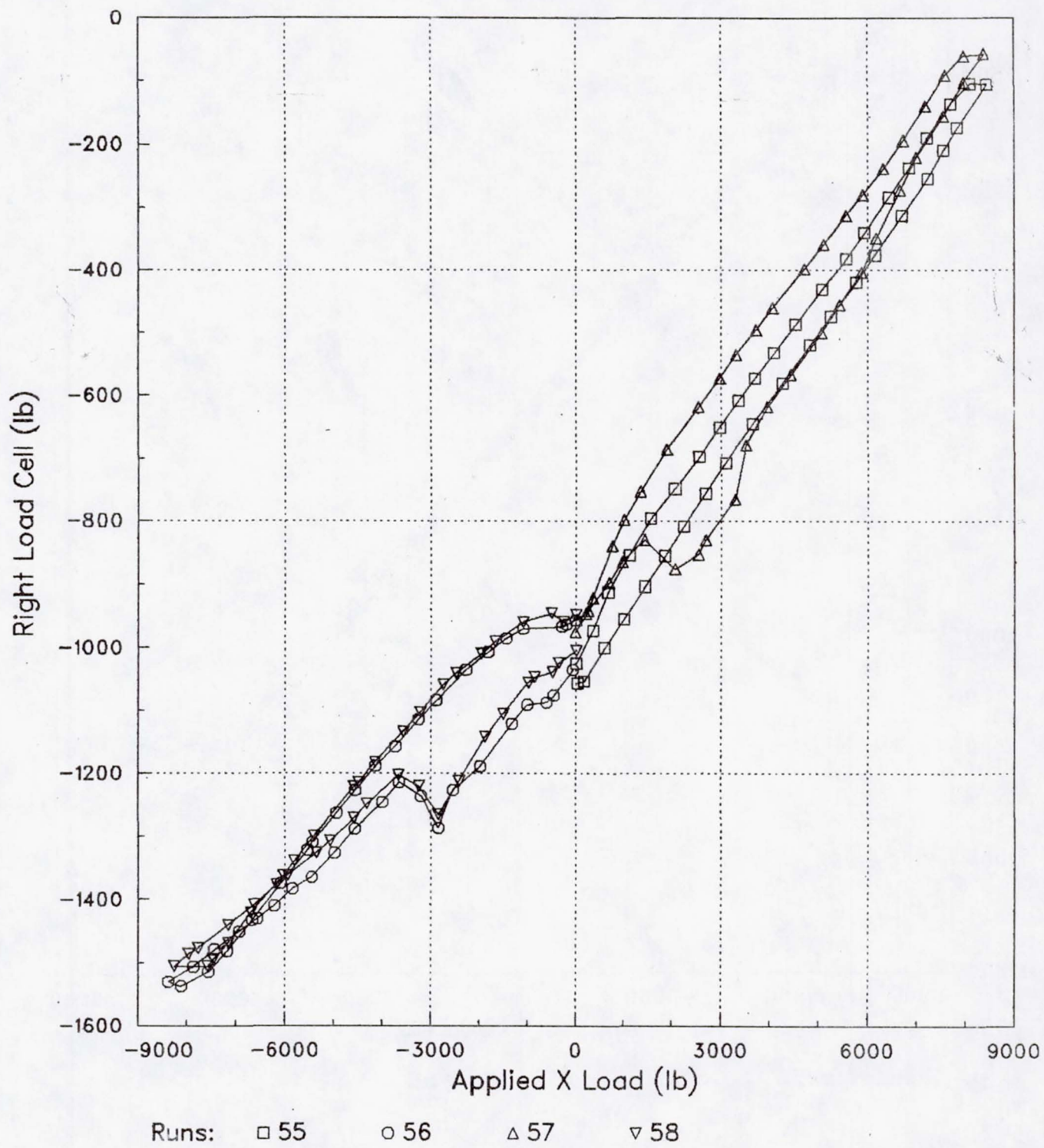
Page intentionally left blank

Applied X Load
Constant Loads: None

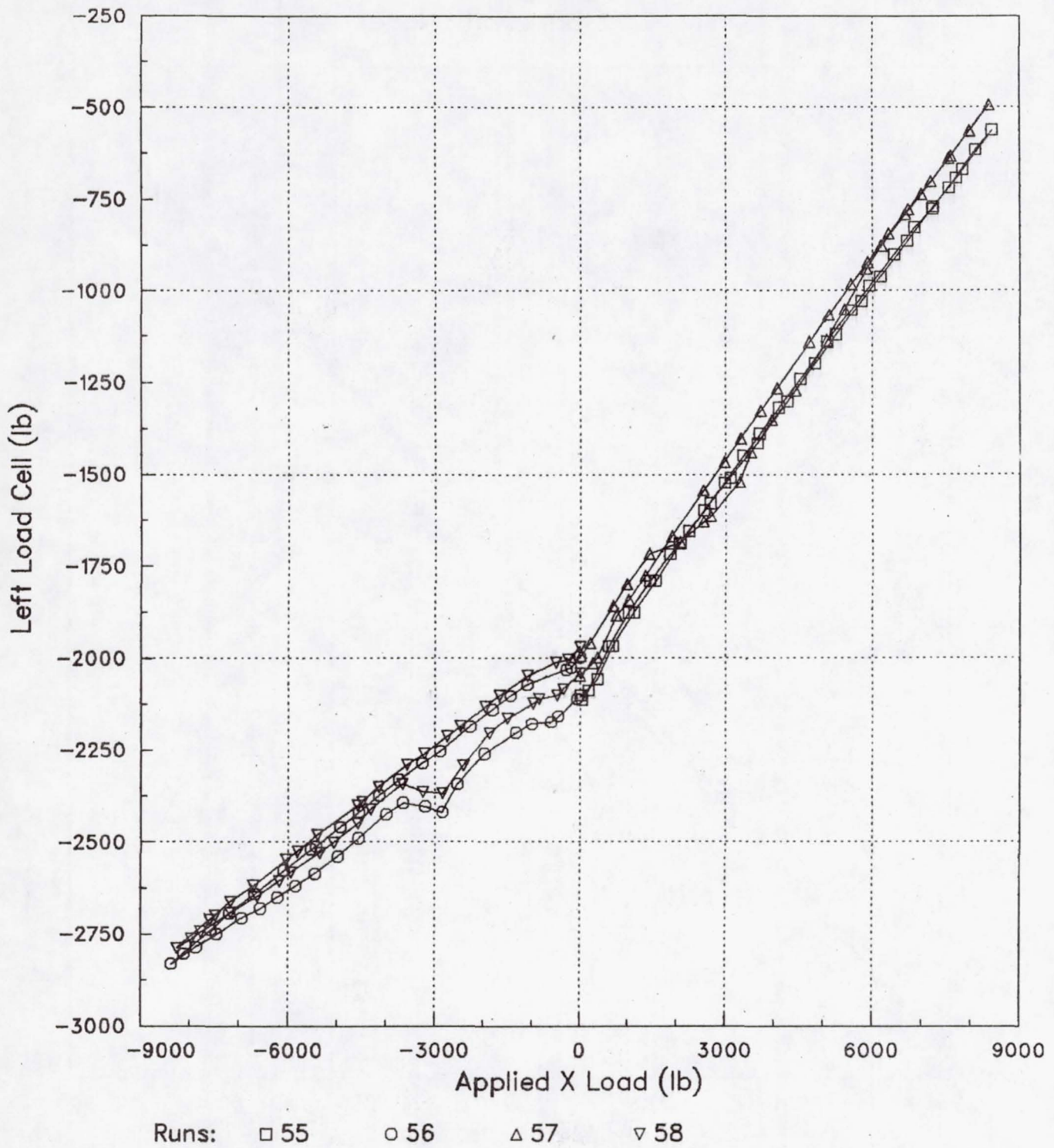


RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: None

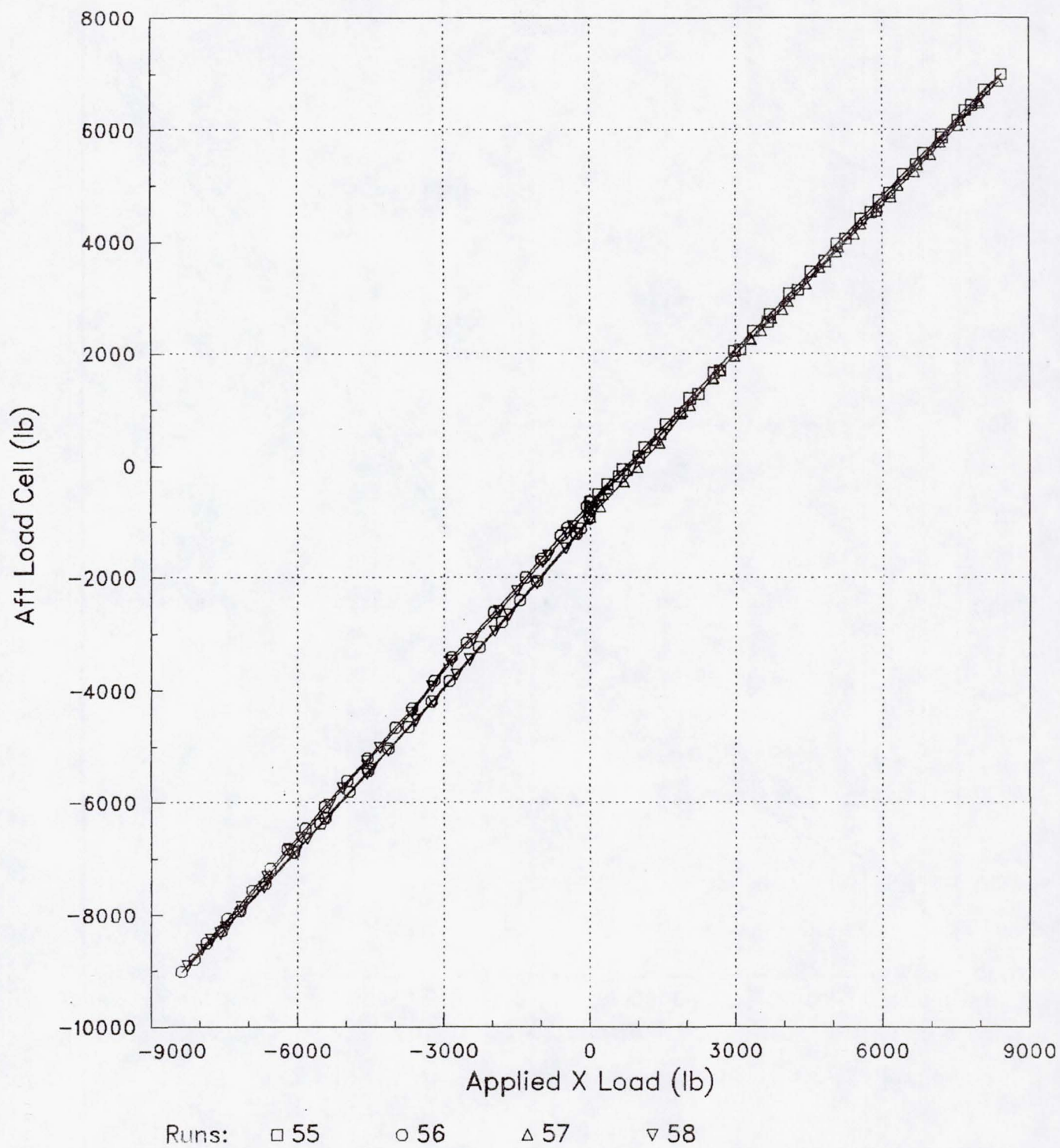


Applied X Load
Constant Loads: None



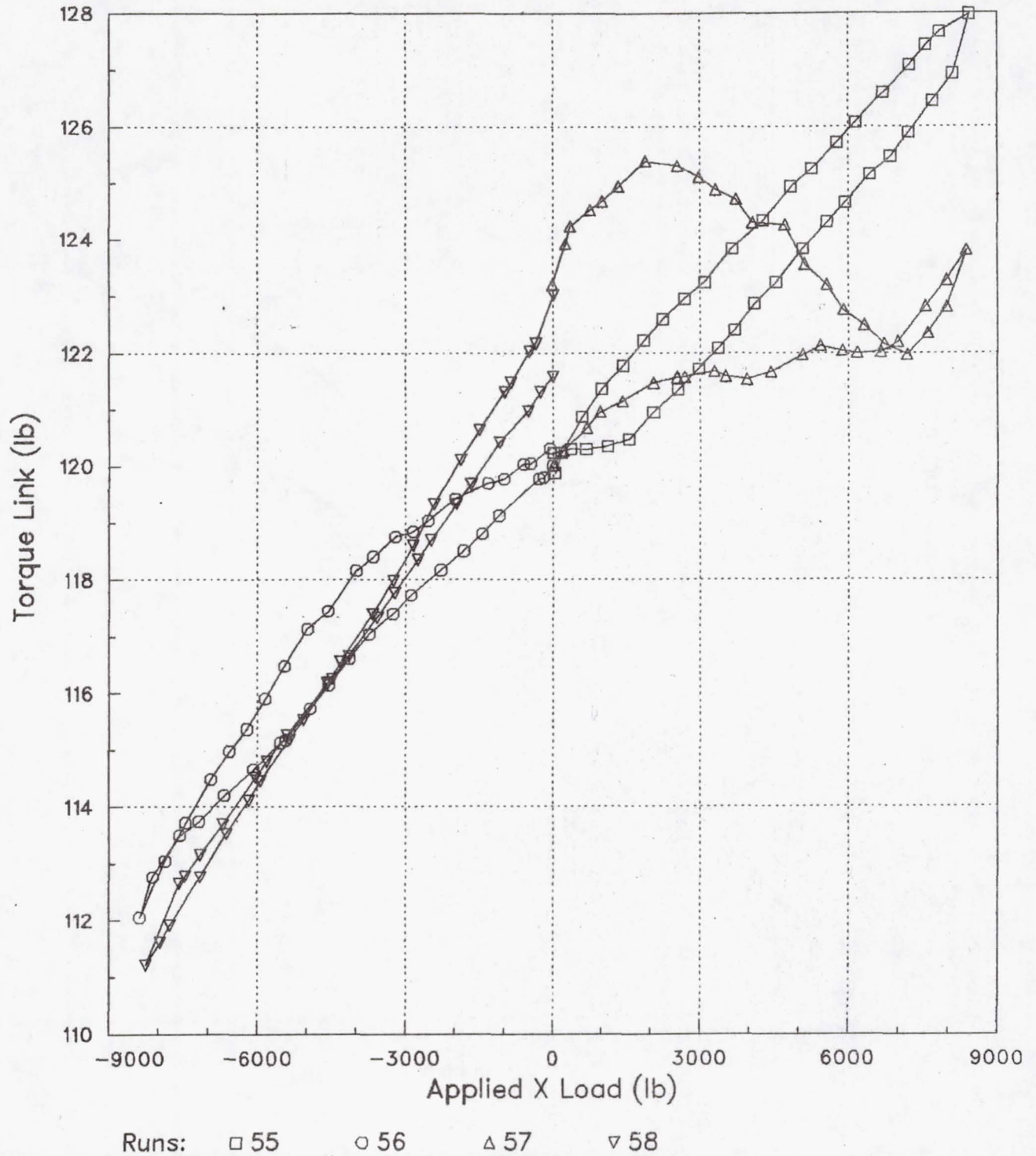
RORA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: None

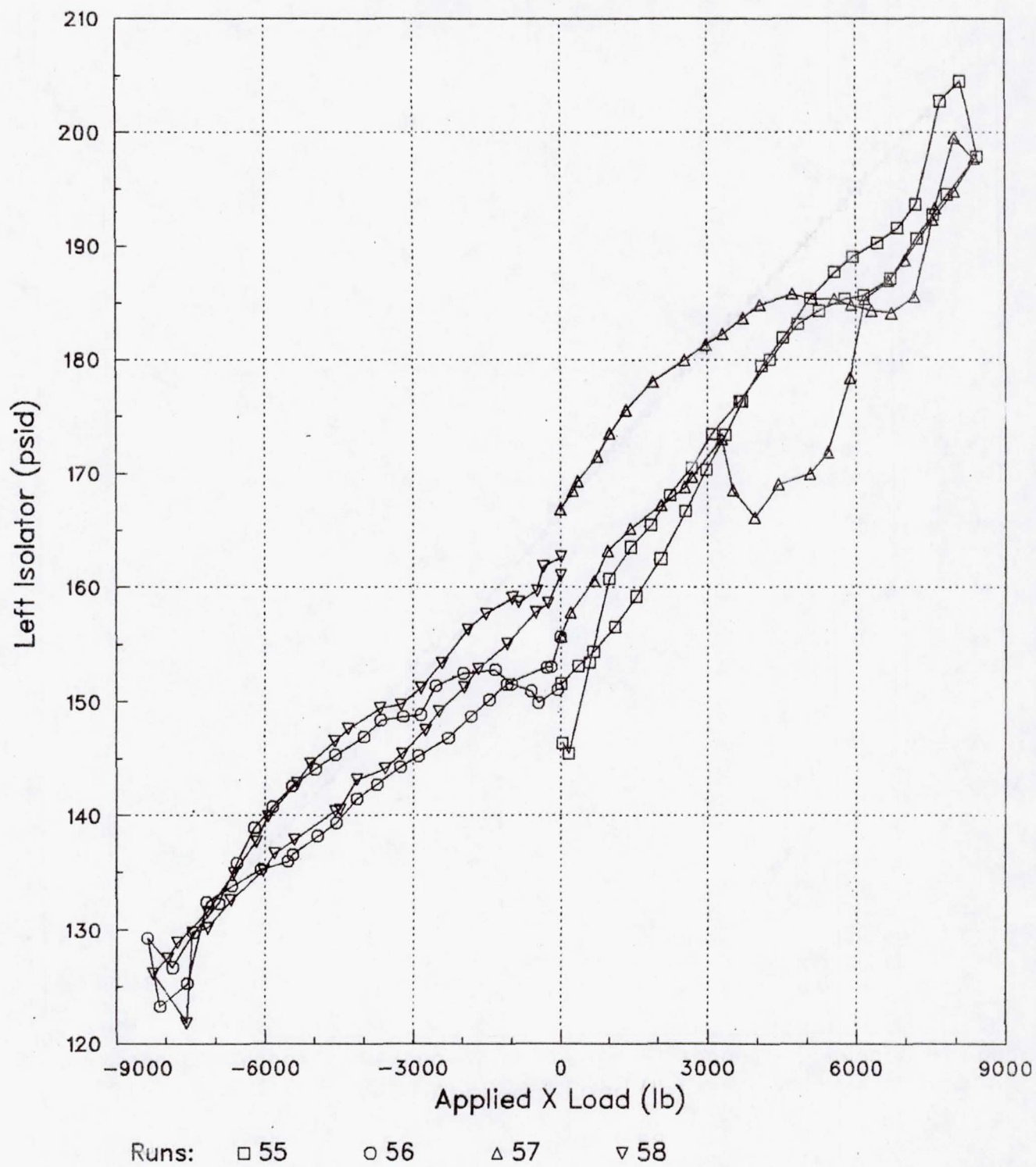


RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: None

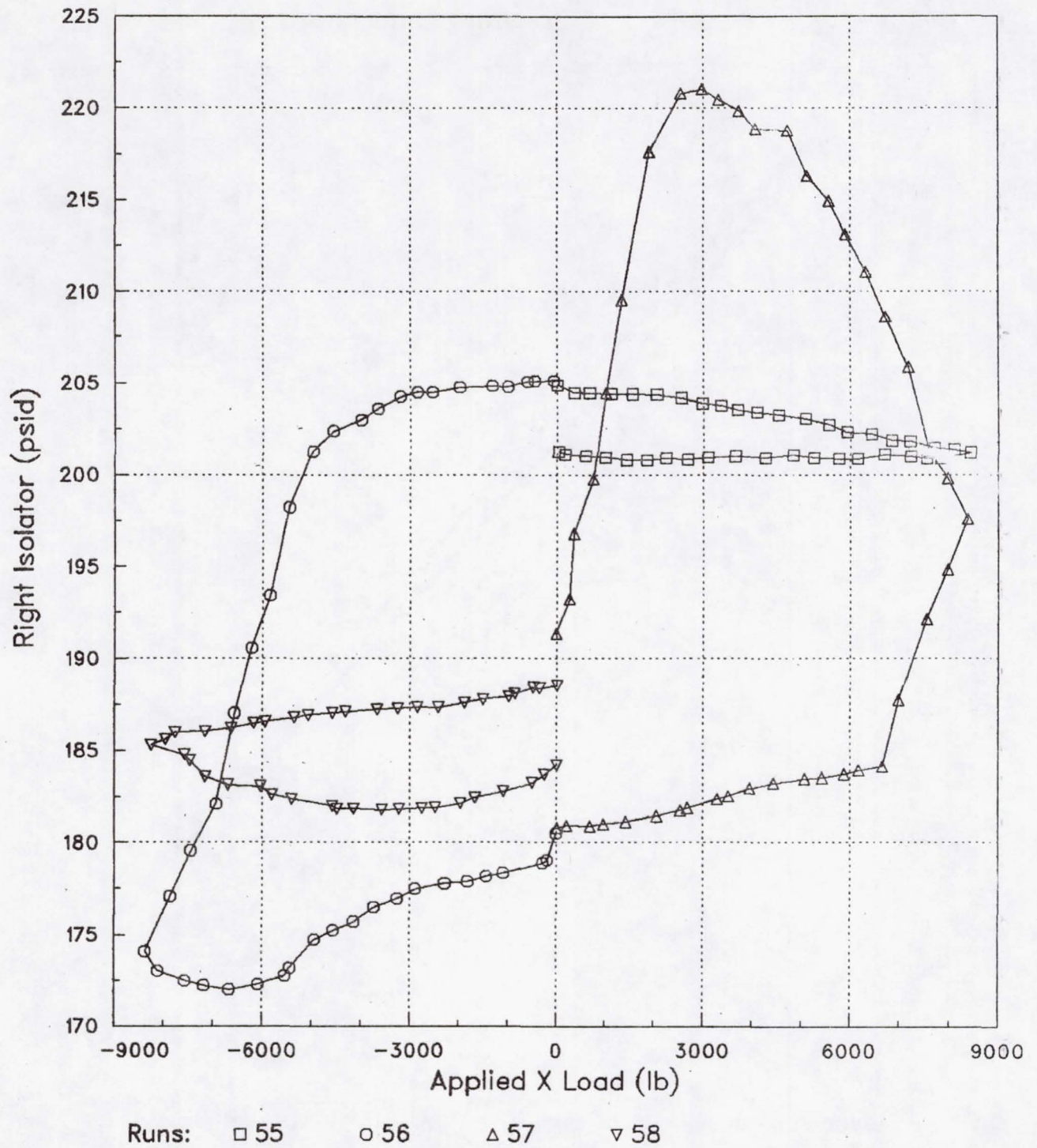


Applied X Load
Constant Loads: None



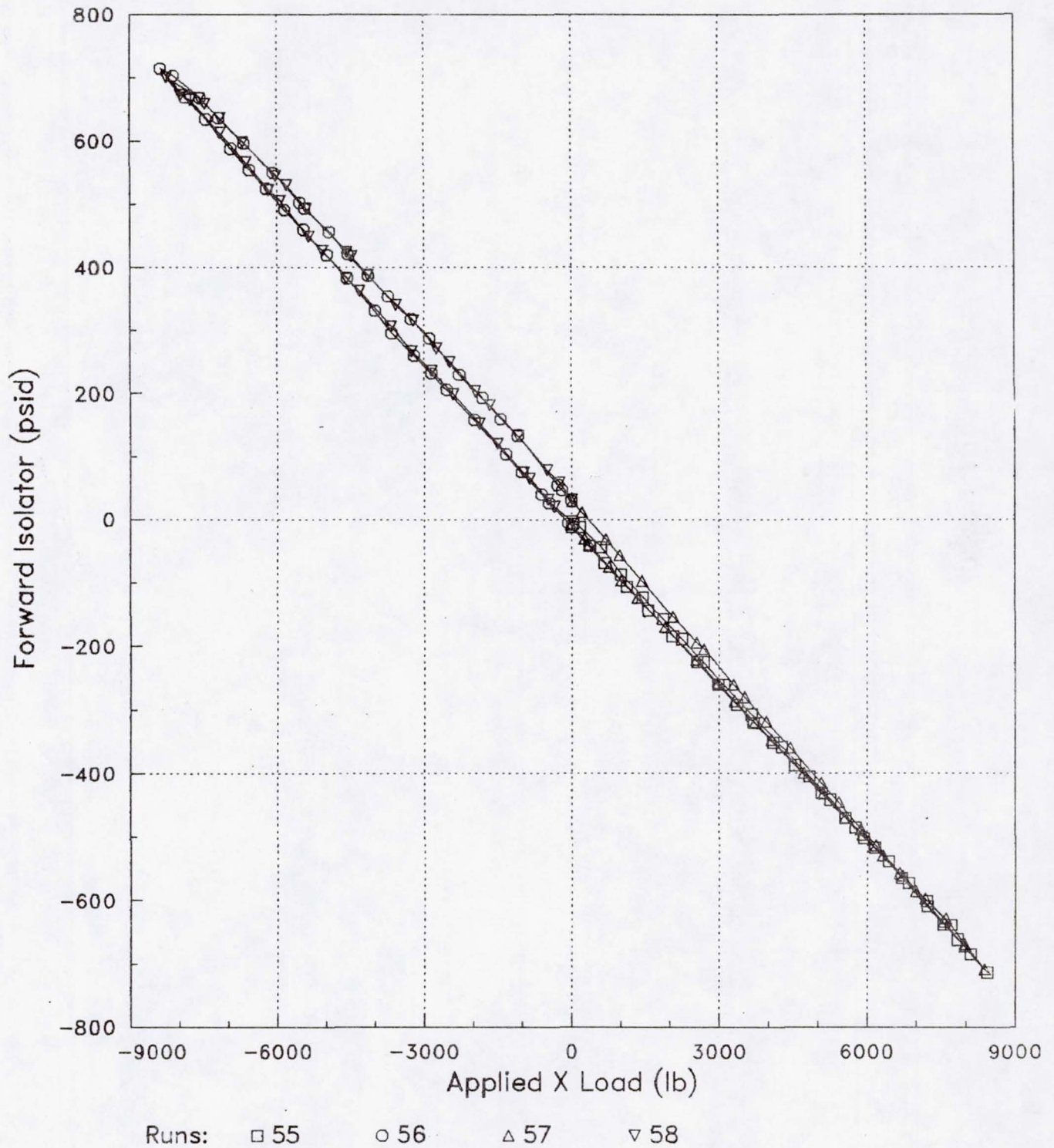
Applied X Load

Constant Loads: None

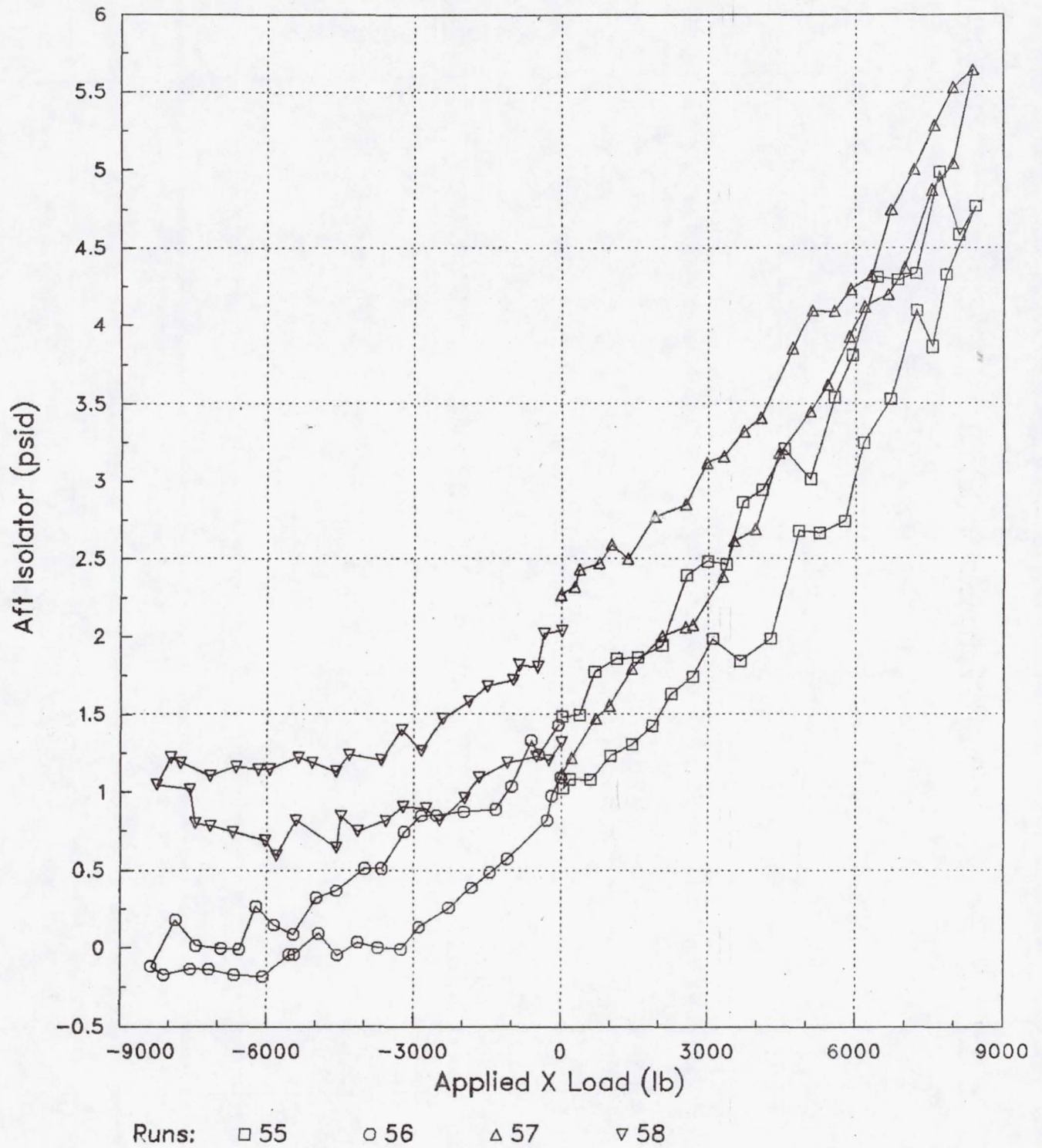


RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: None

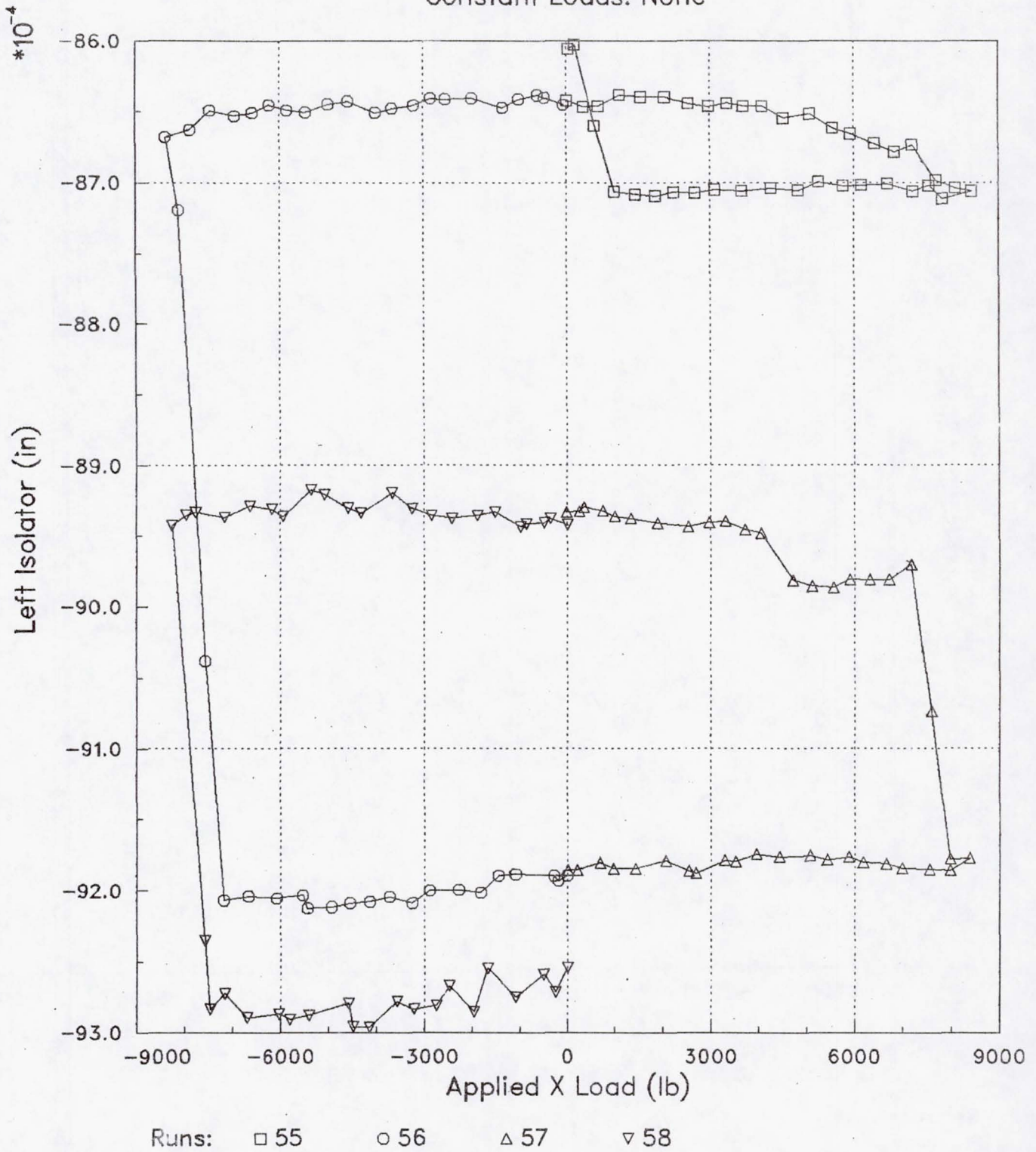


Applied X Load
Constant Loads: None

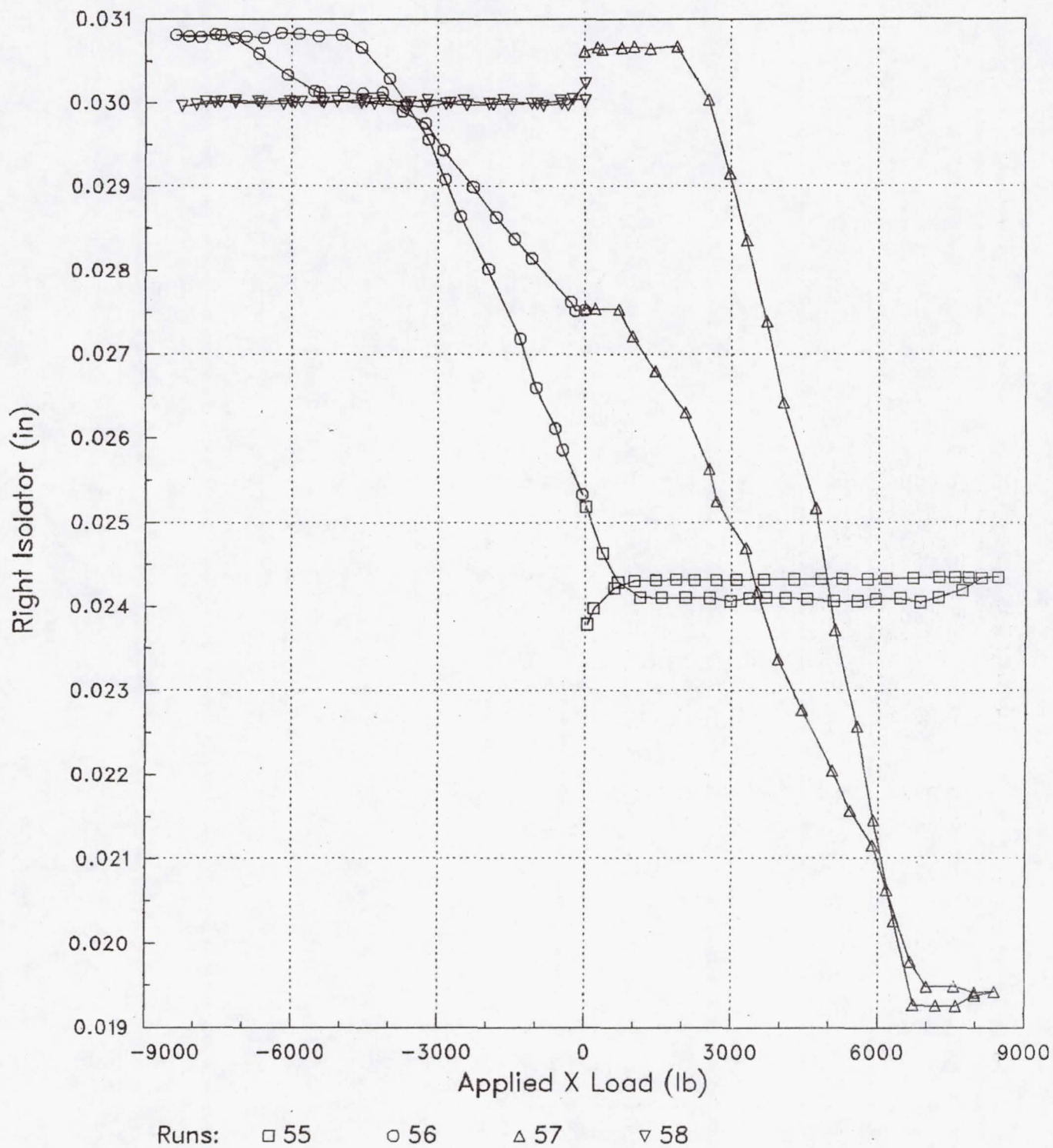


FSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: None

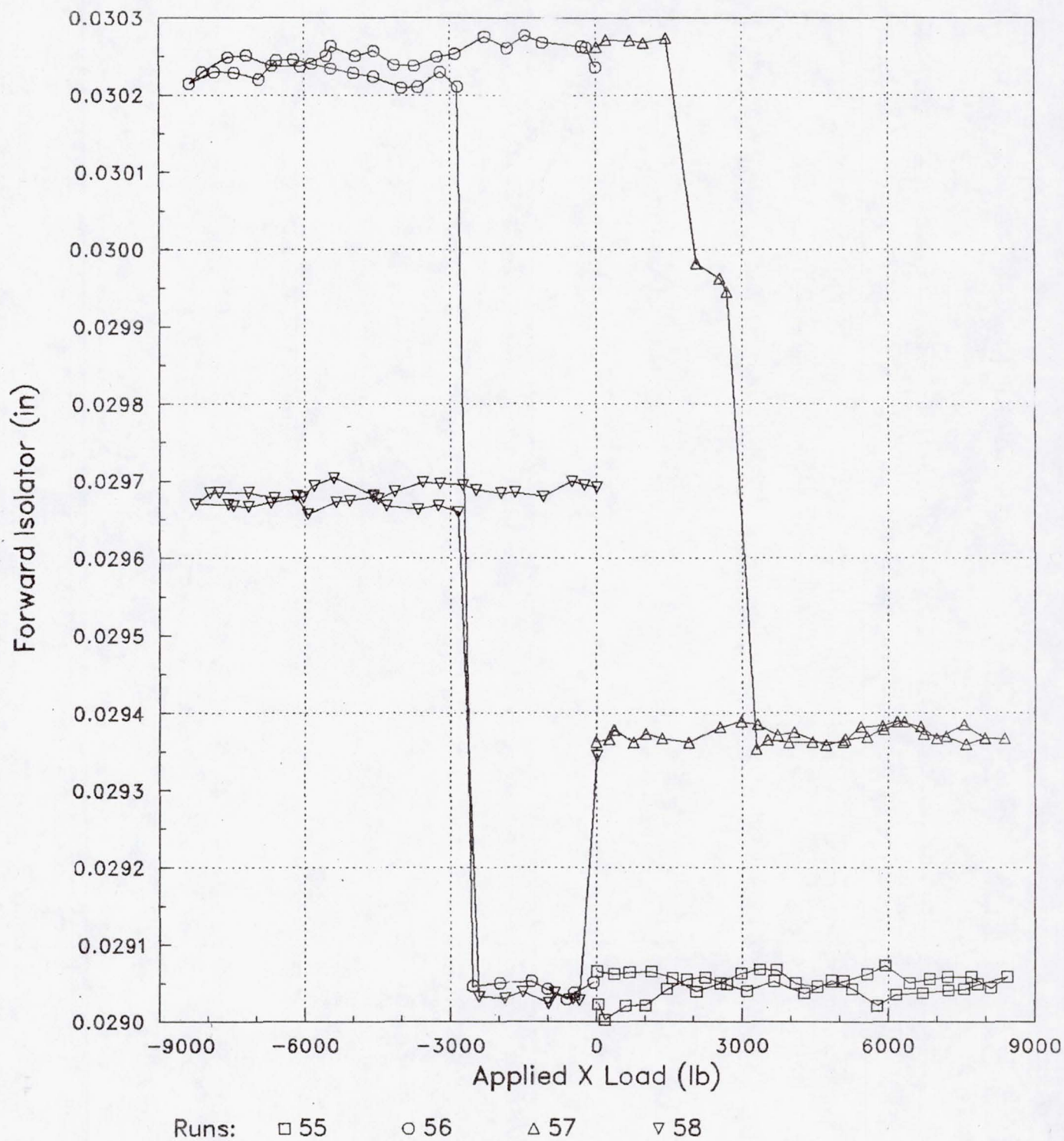


Applied X Load
Constant Loads: None



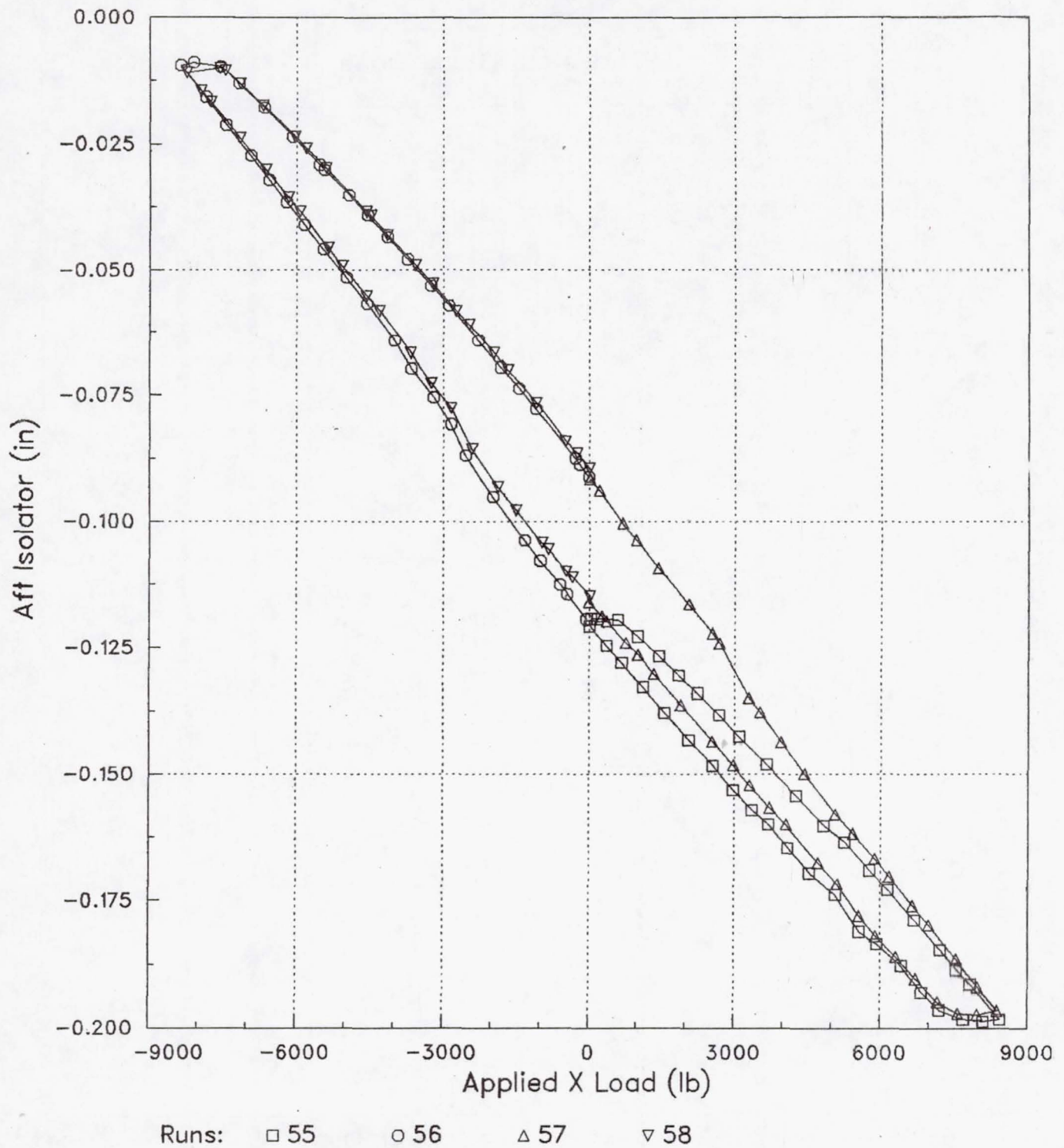
RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: None



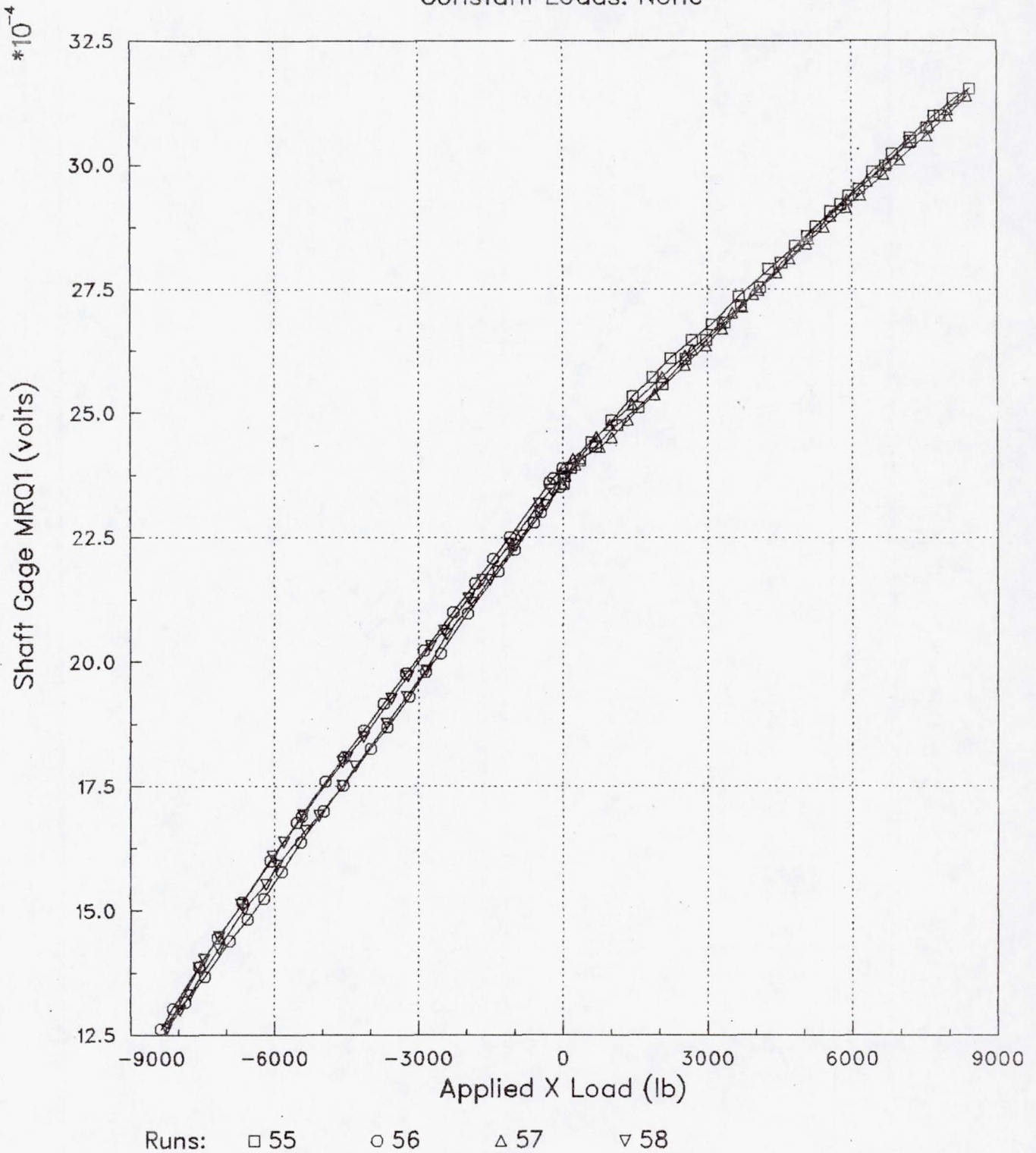
Applied X Load

Constant Loads: None

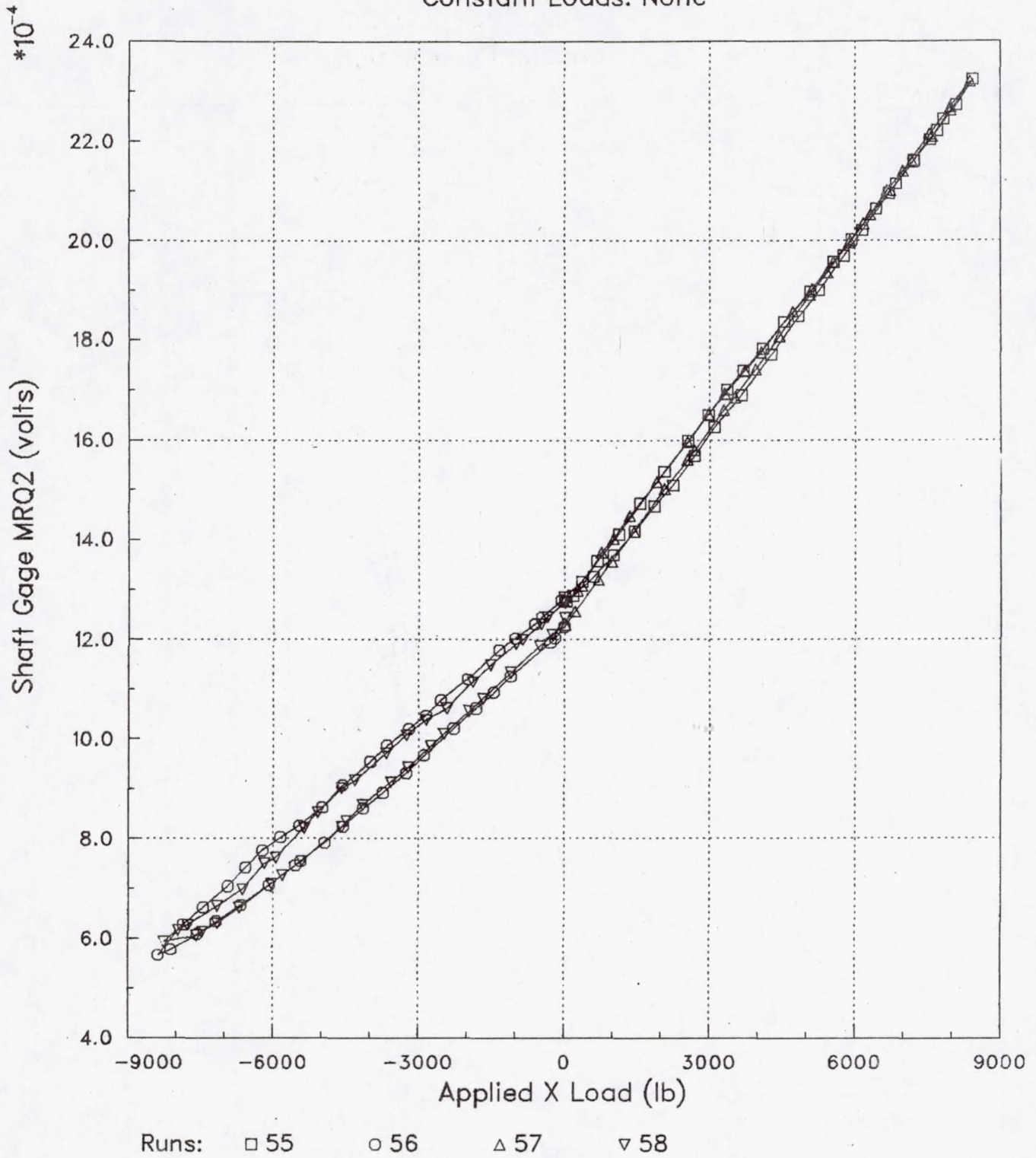


RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: None

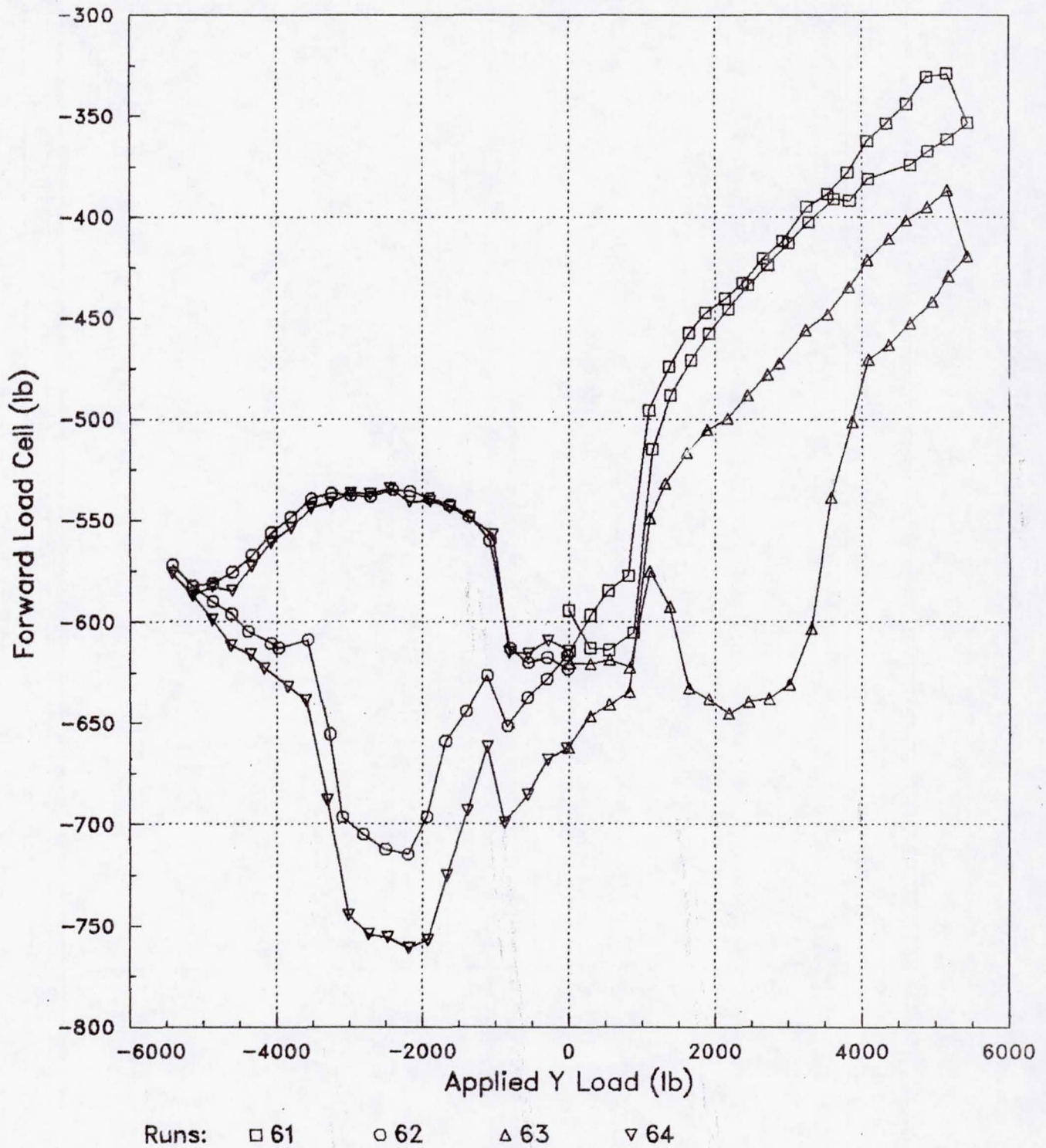


Applied X Load
Constant Loads: None

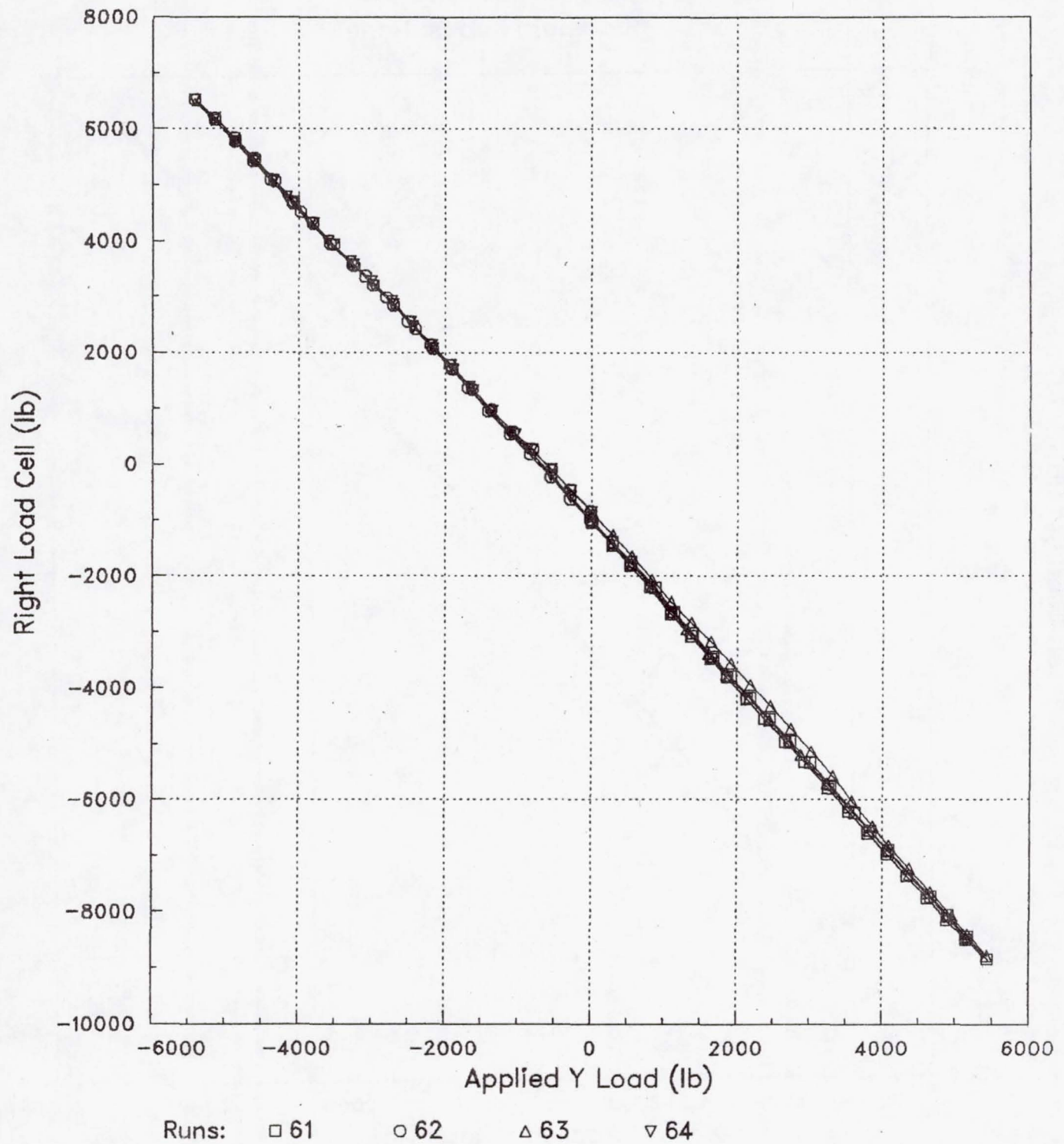


RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None

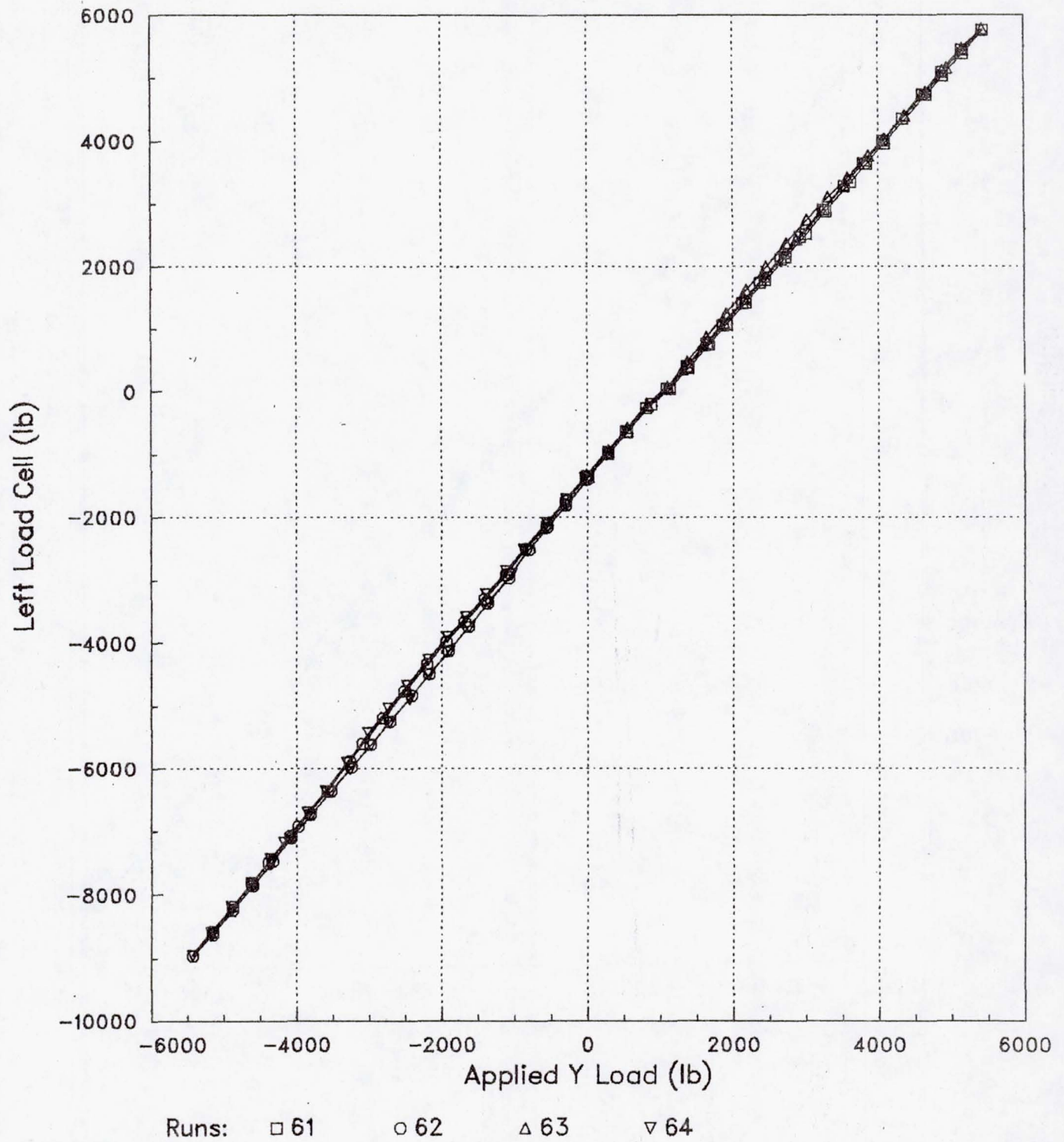


Applied Y Load
Constant Loads: None

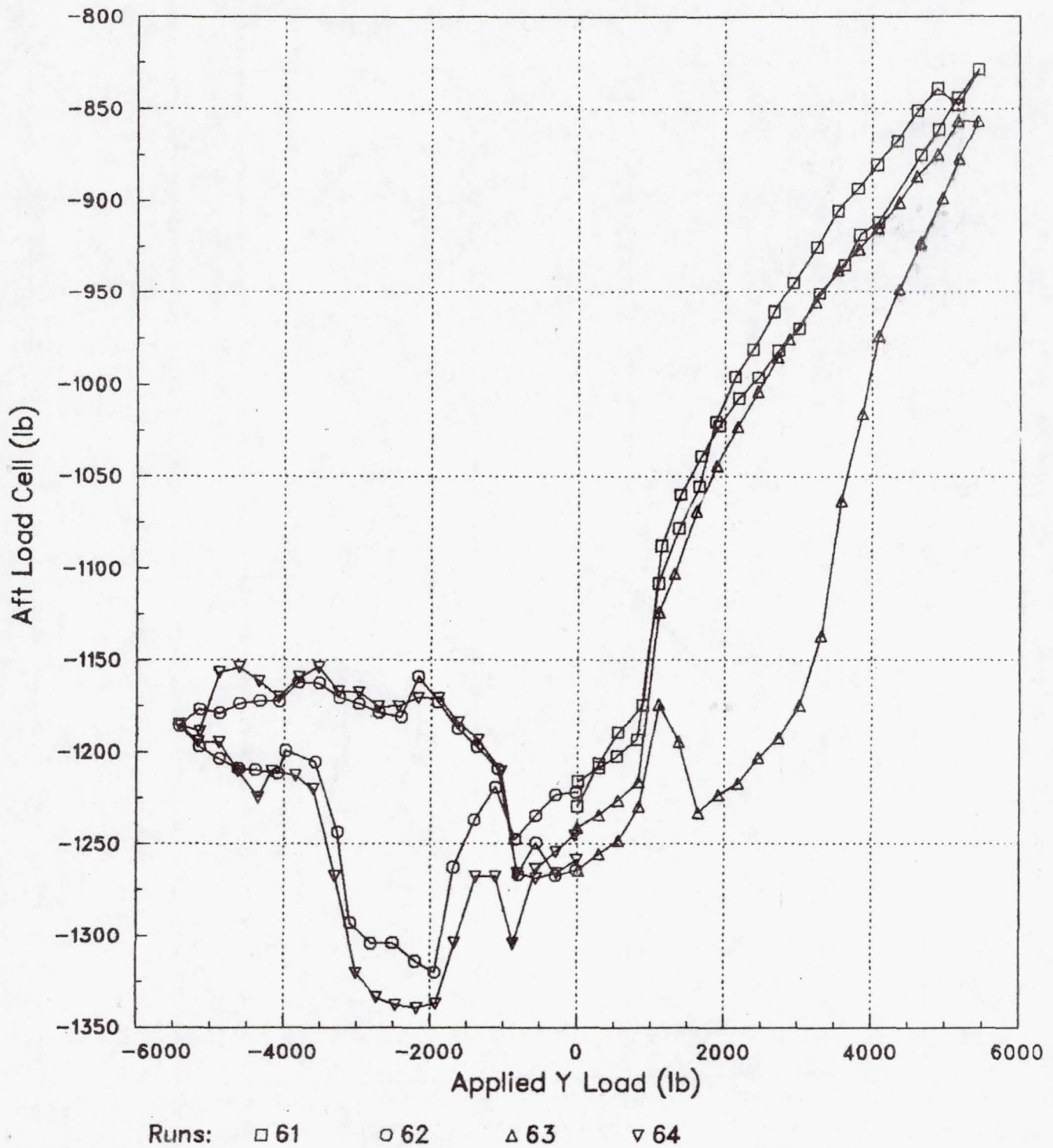


RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None

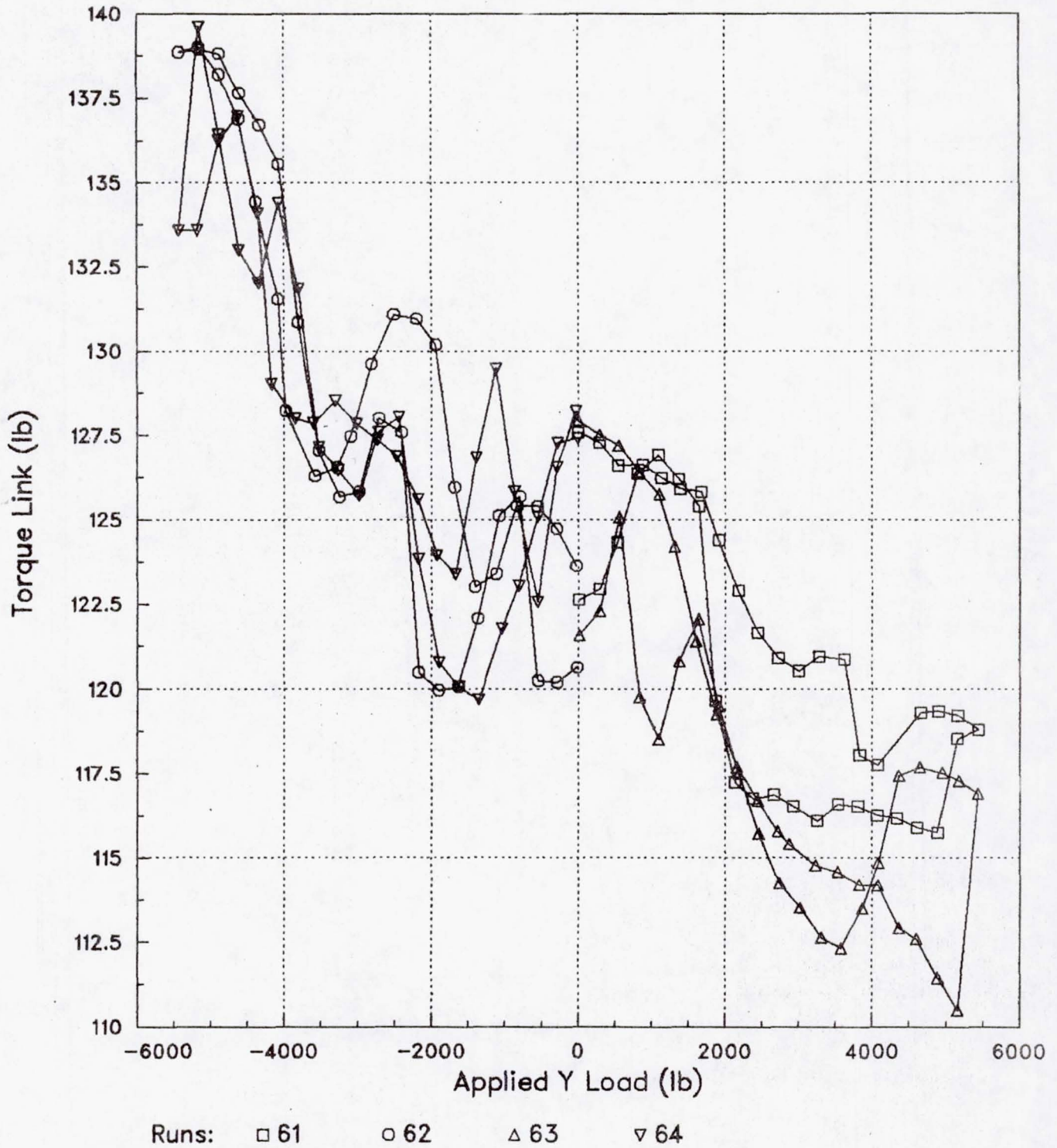


Applied Y Load
Constant Loads: None

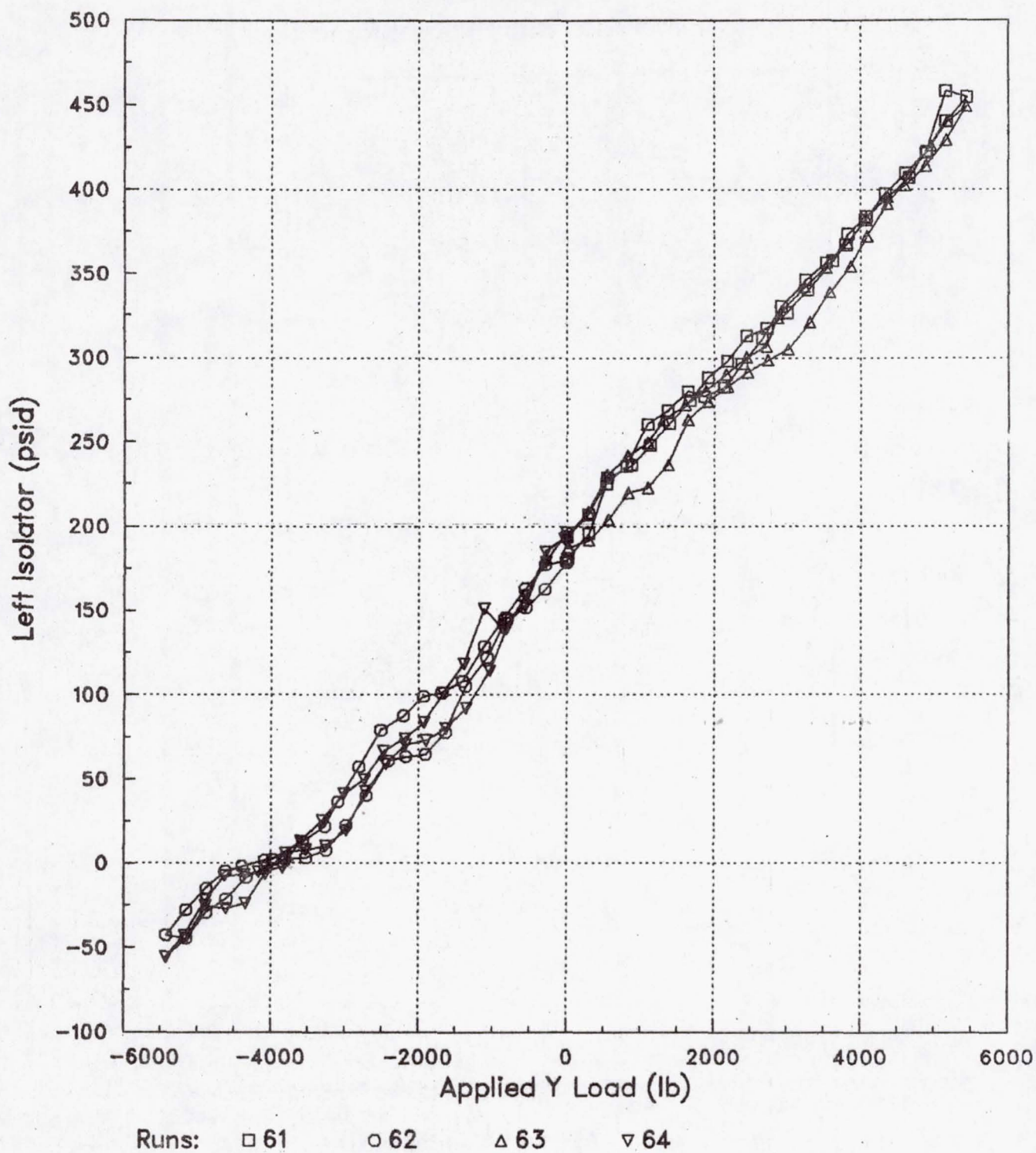


RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None

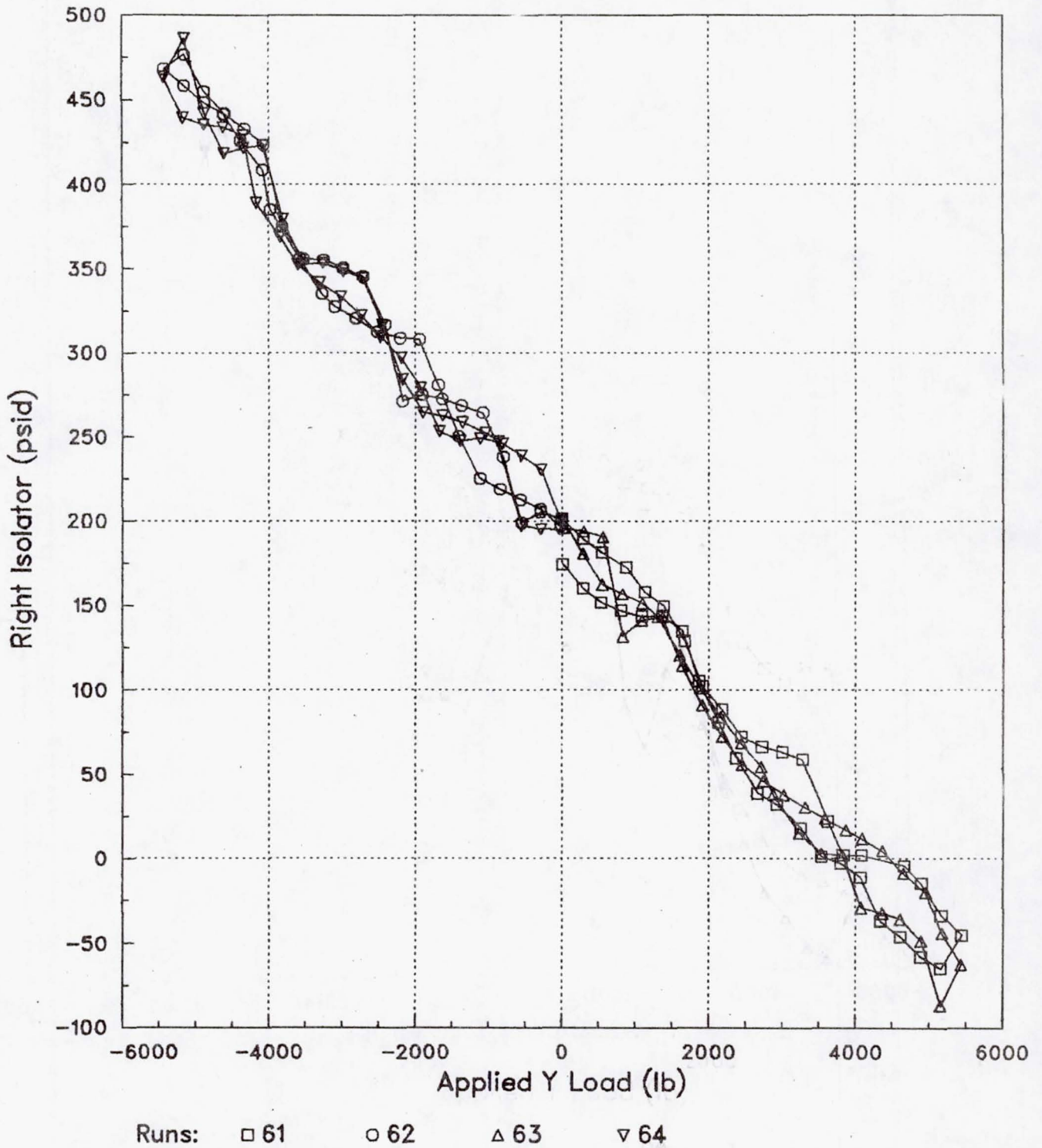


Applied Y Load
Constant Loads: None



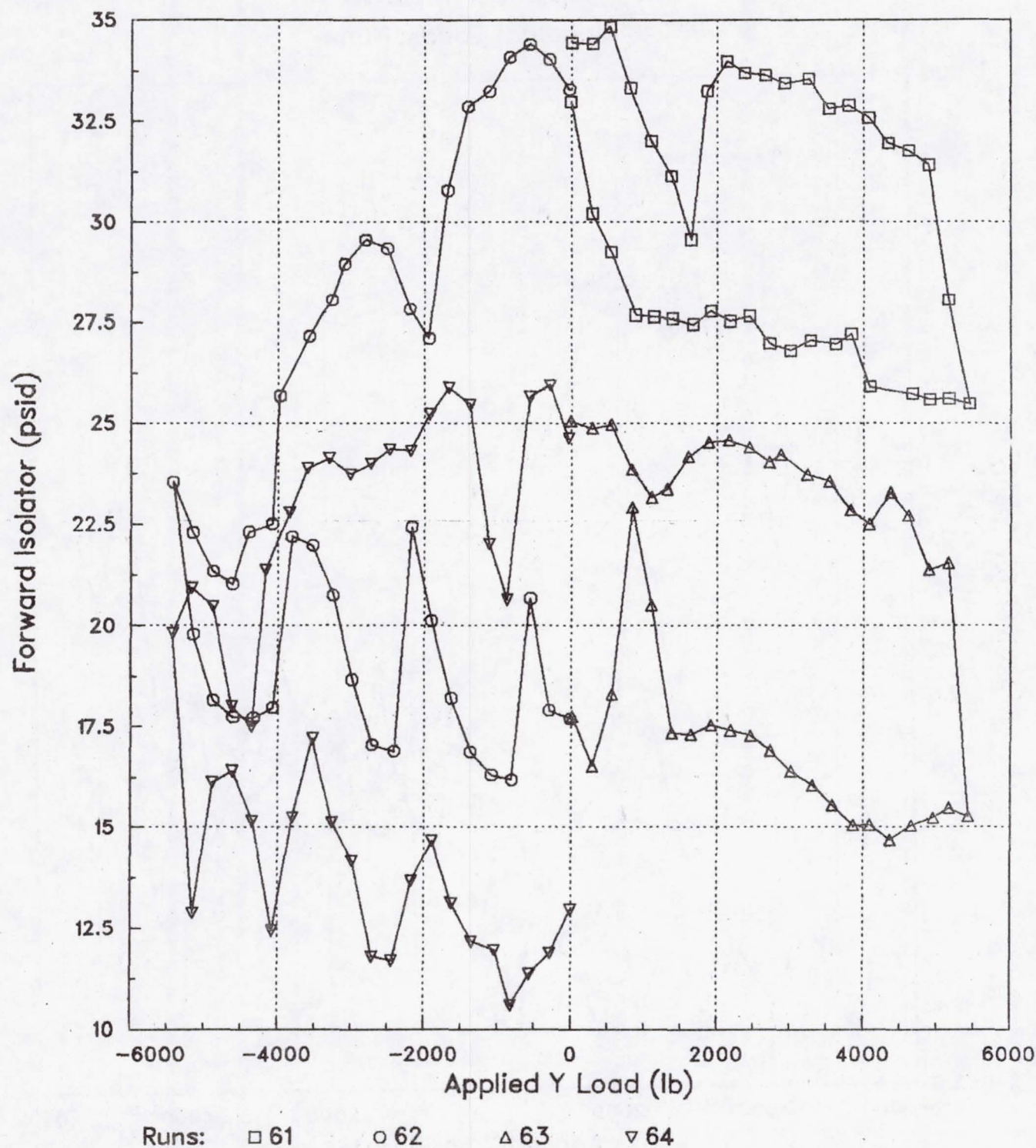
RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None



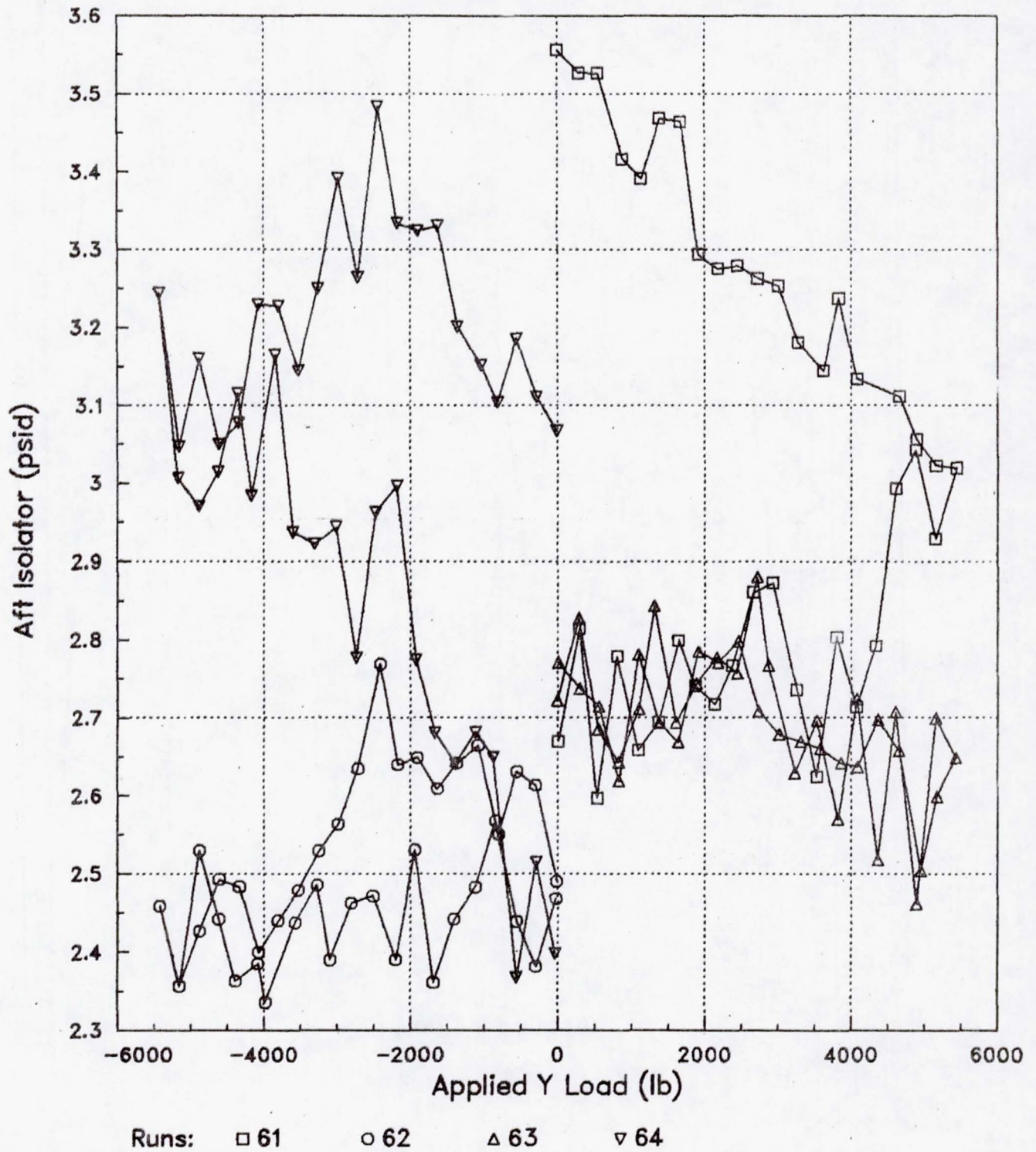
Applied Y Load

Constant Loads: None

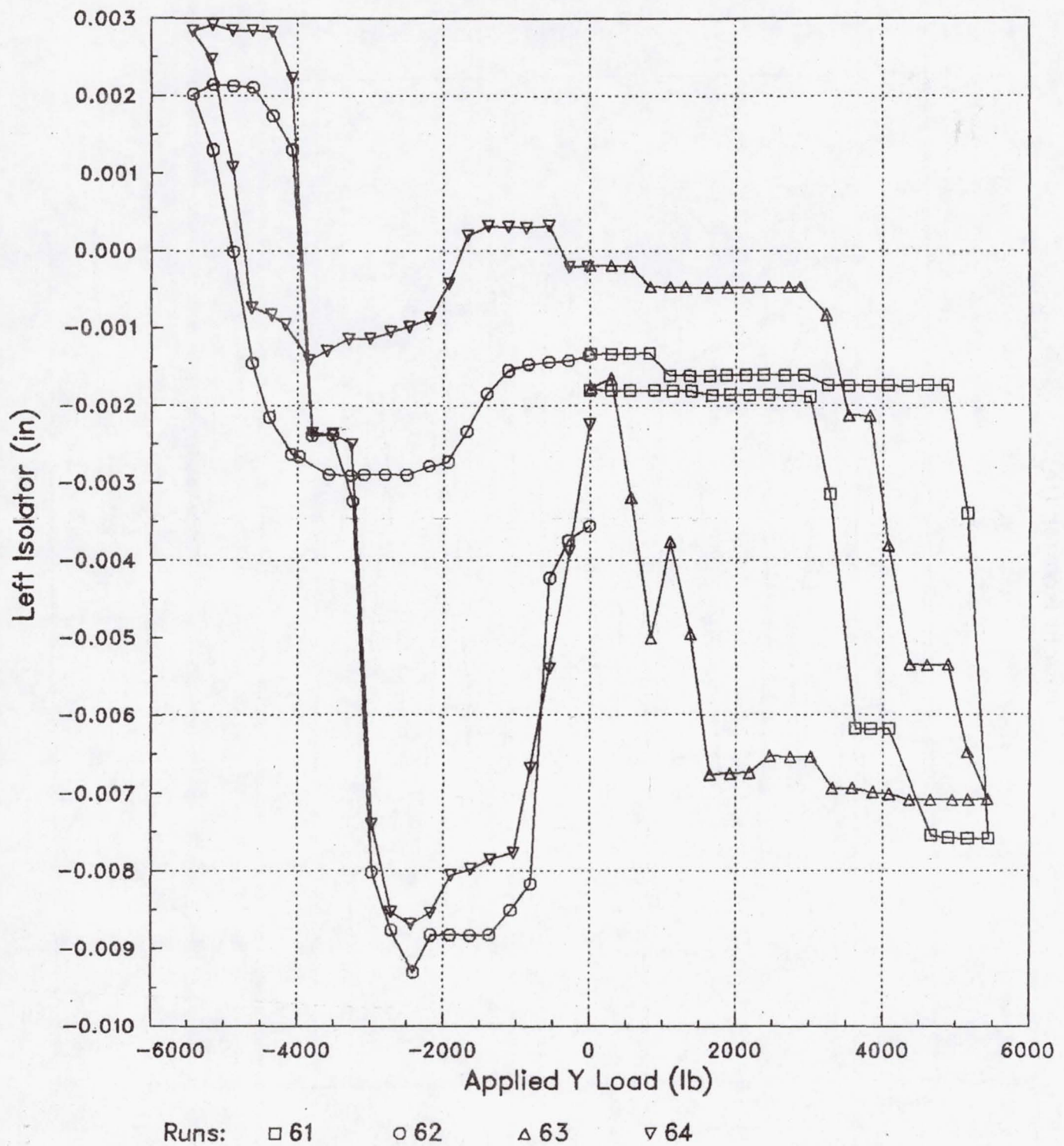


RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None

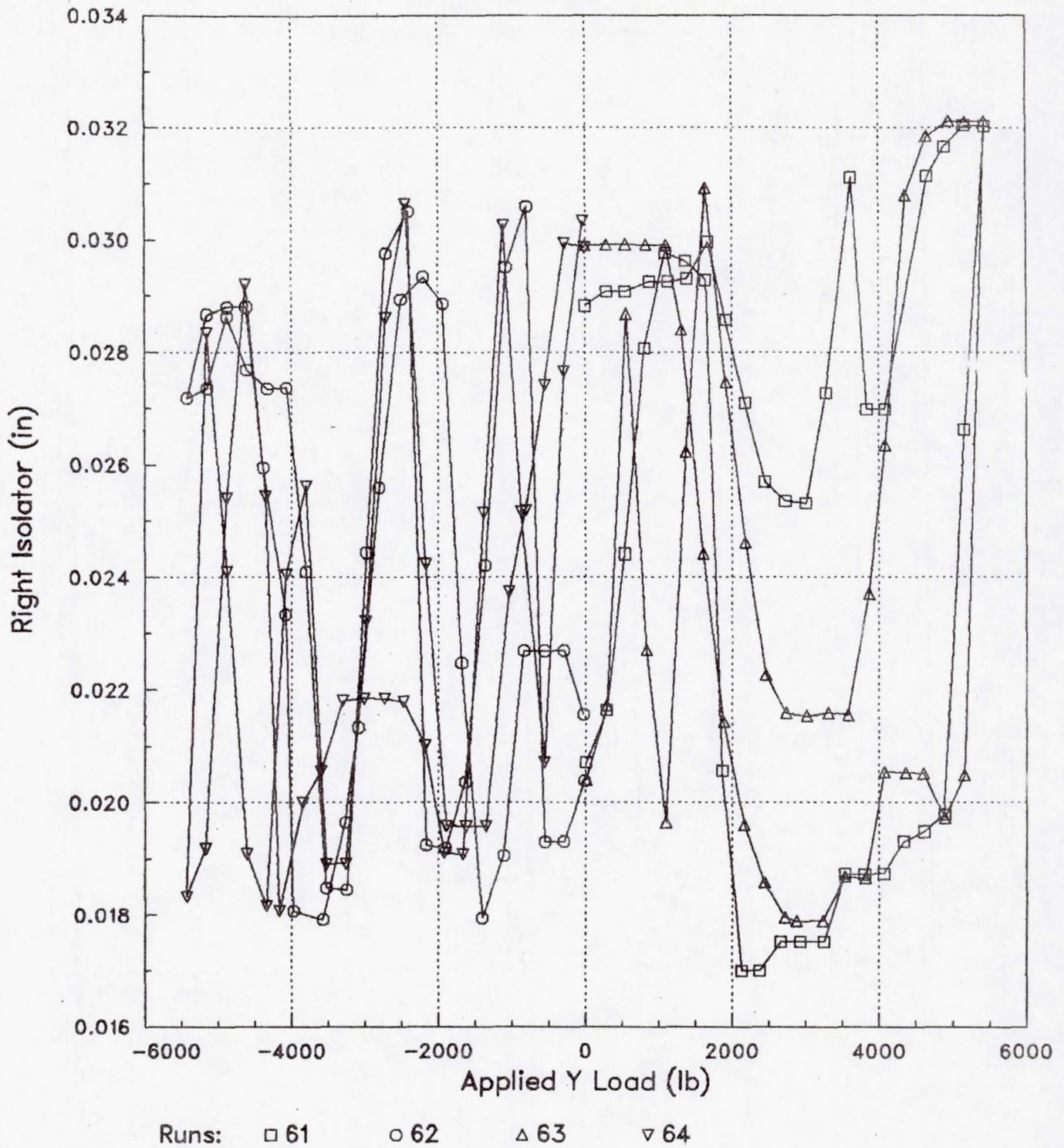


Applied Y Load Constant Loads: None



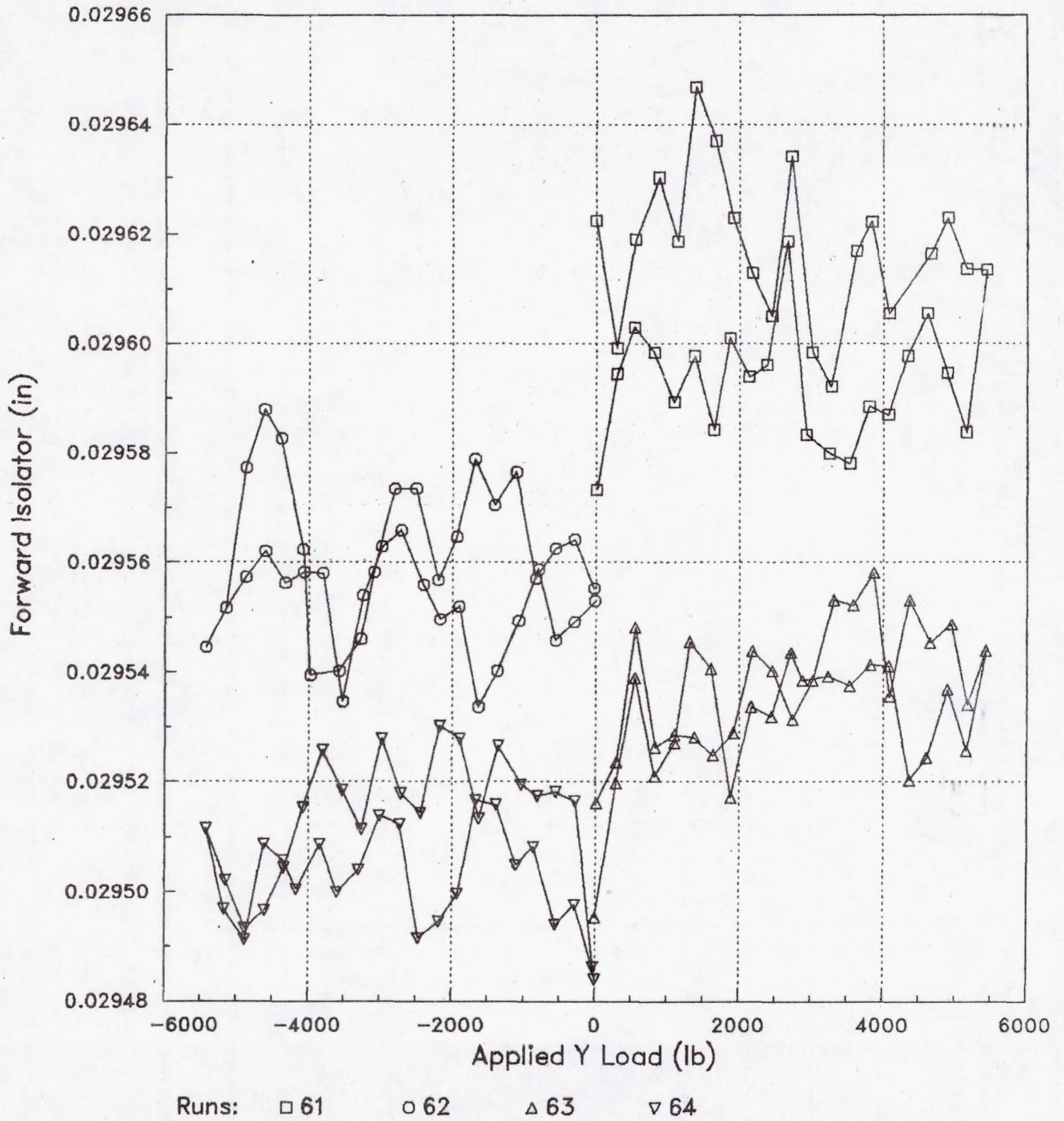
RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None



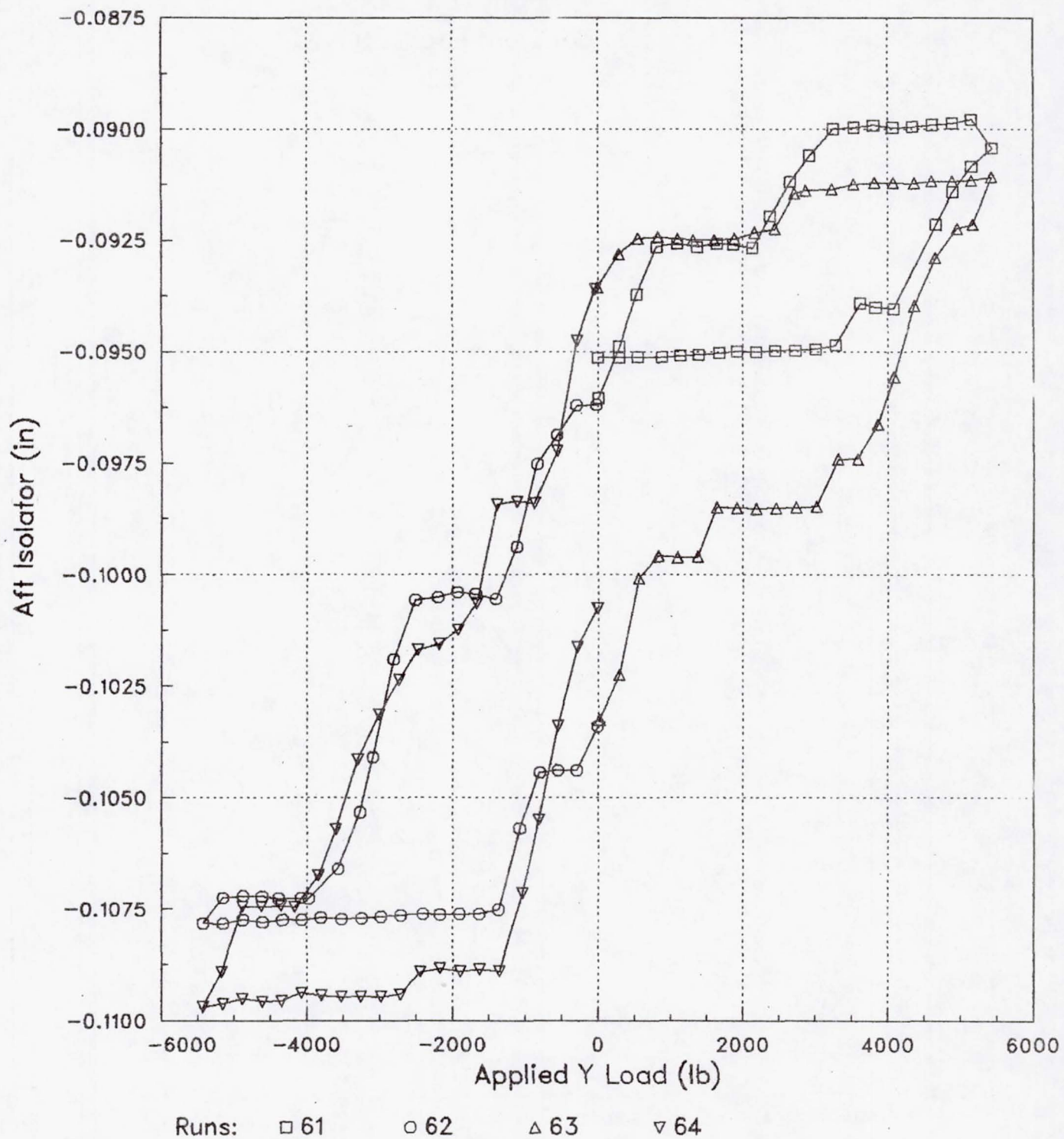
RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None



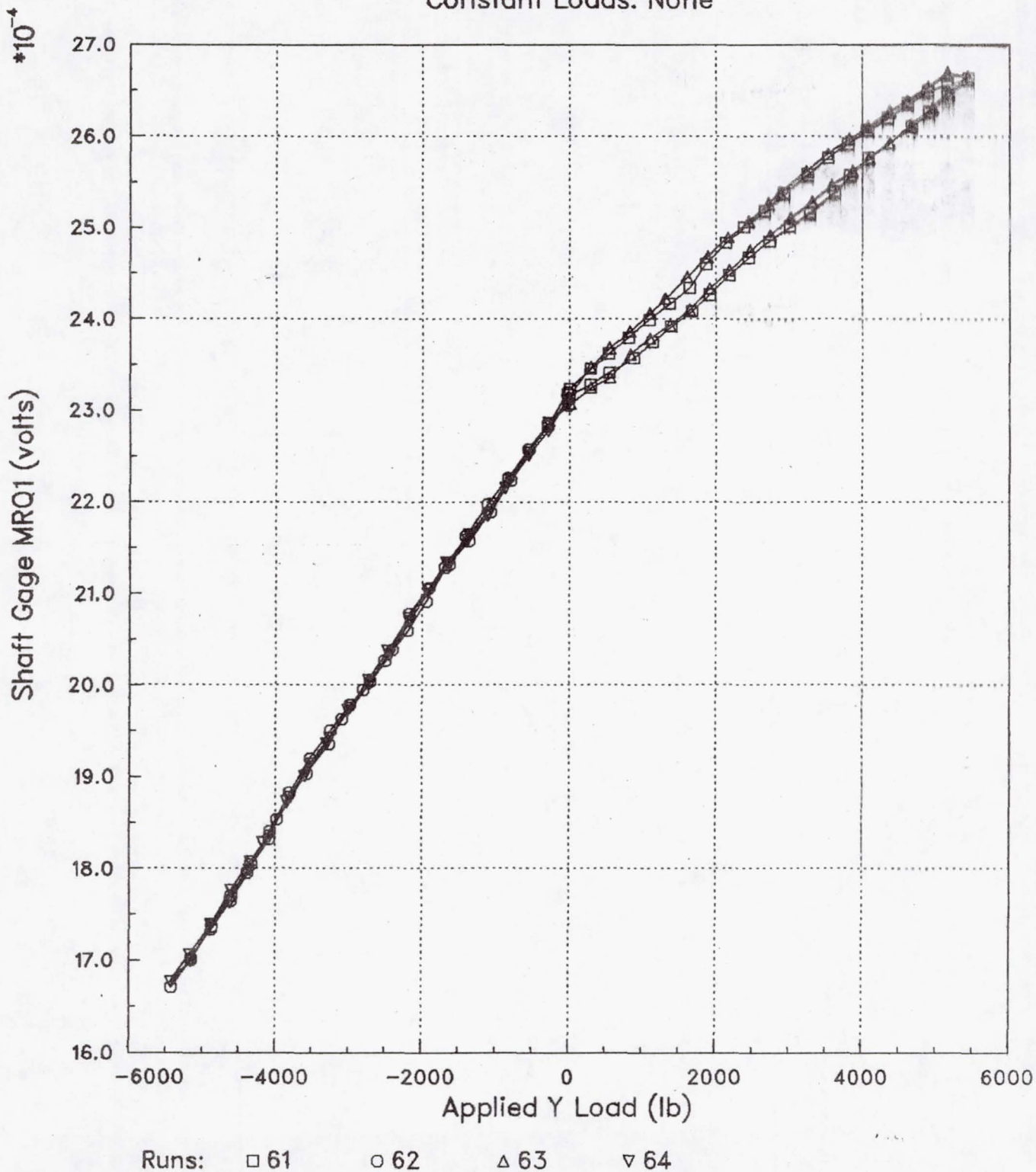
RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None



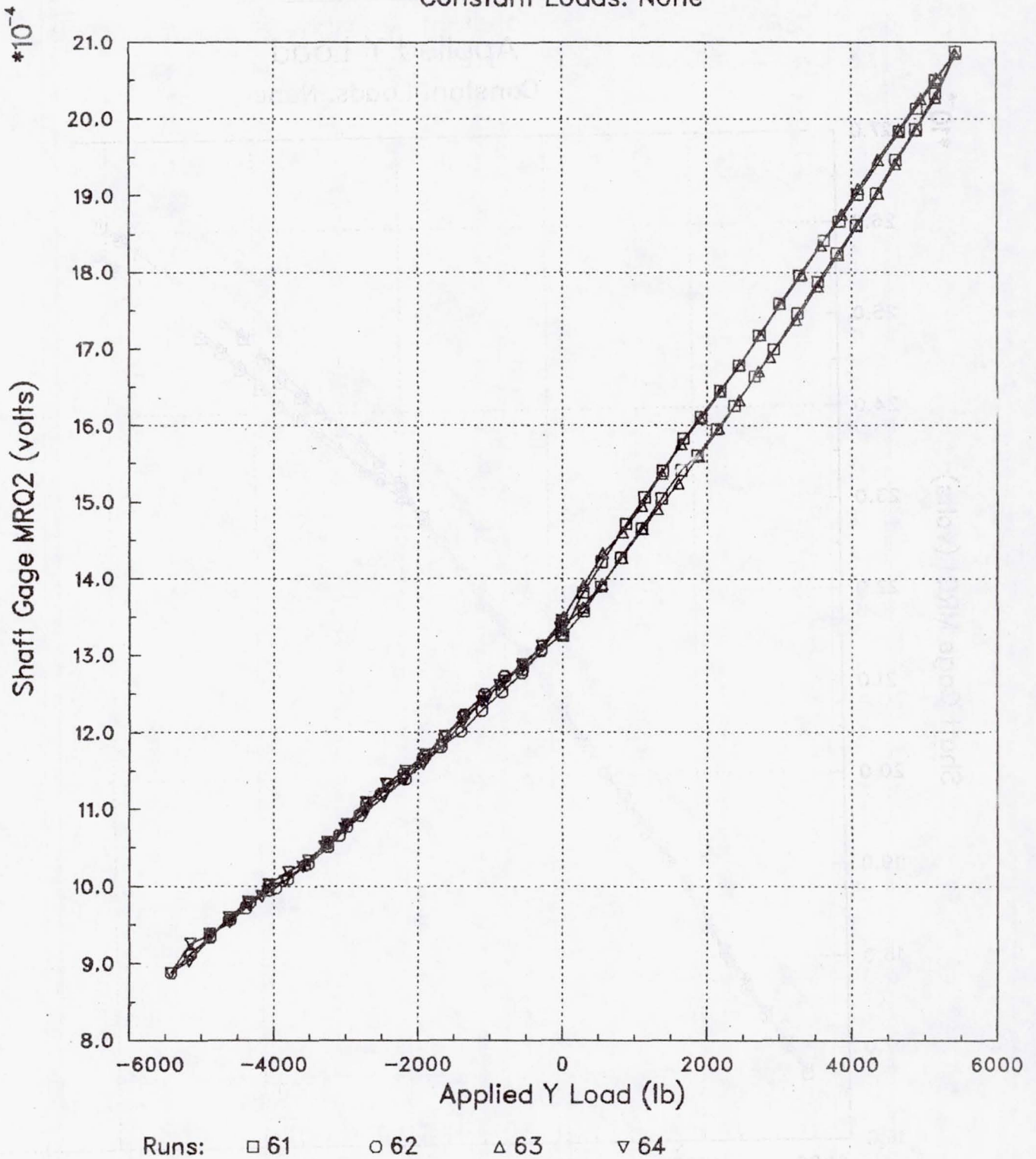
RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None

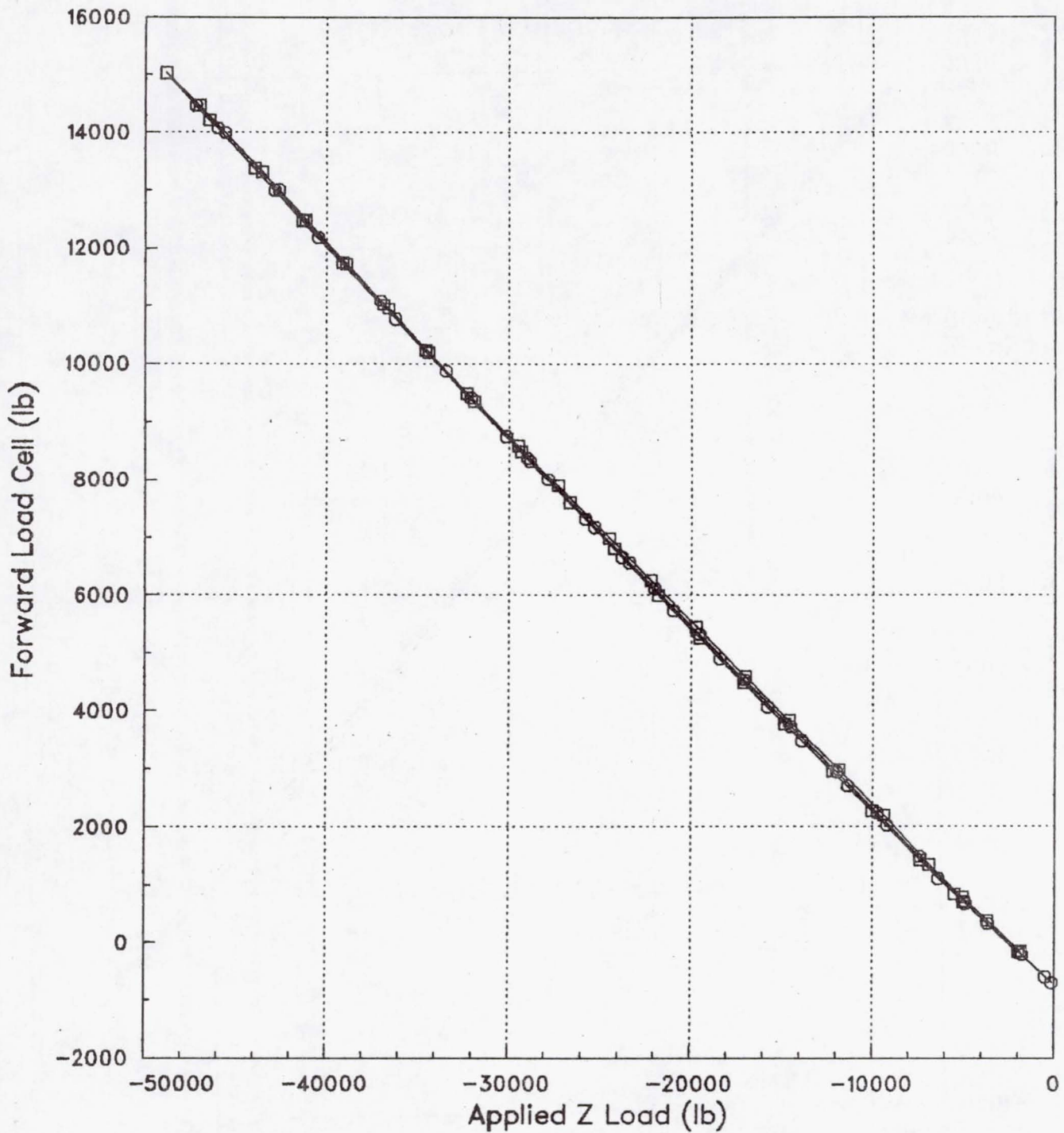


RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: None



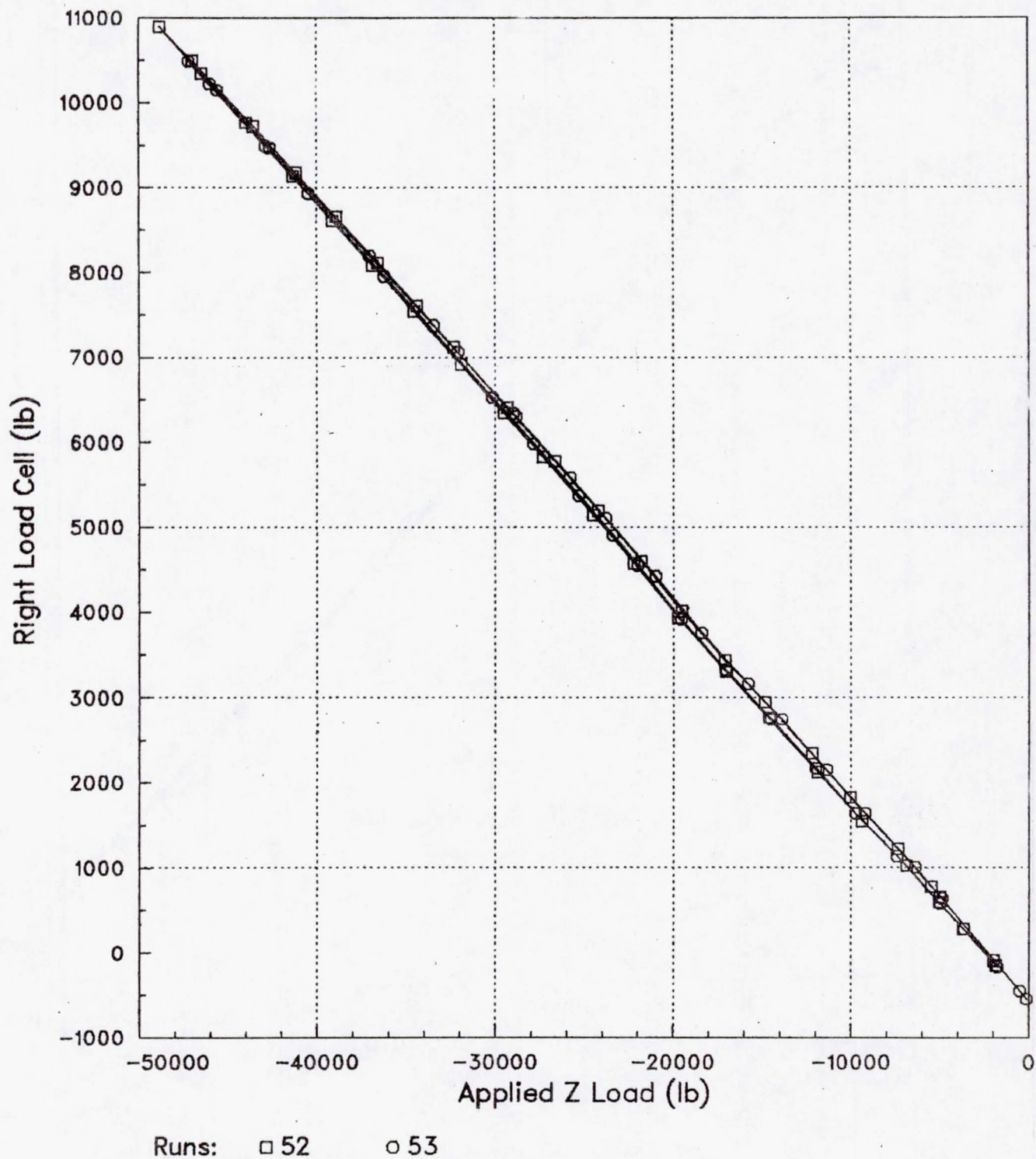
Applied Z Load
Constant Loads: None



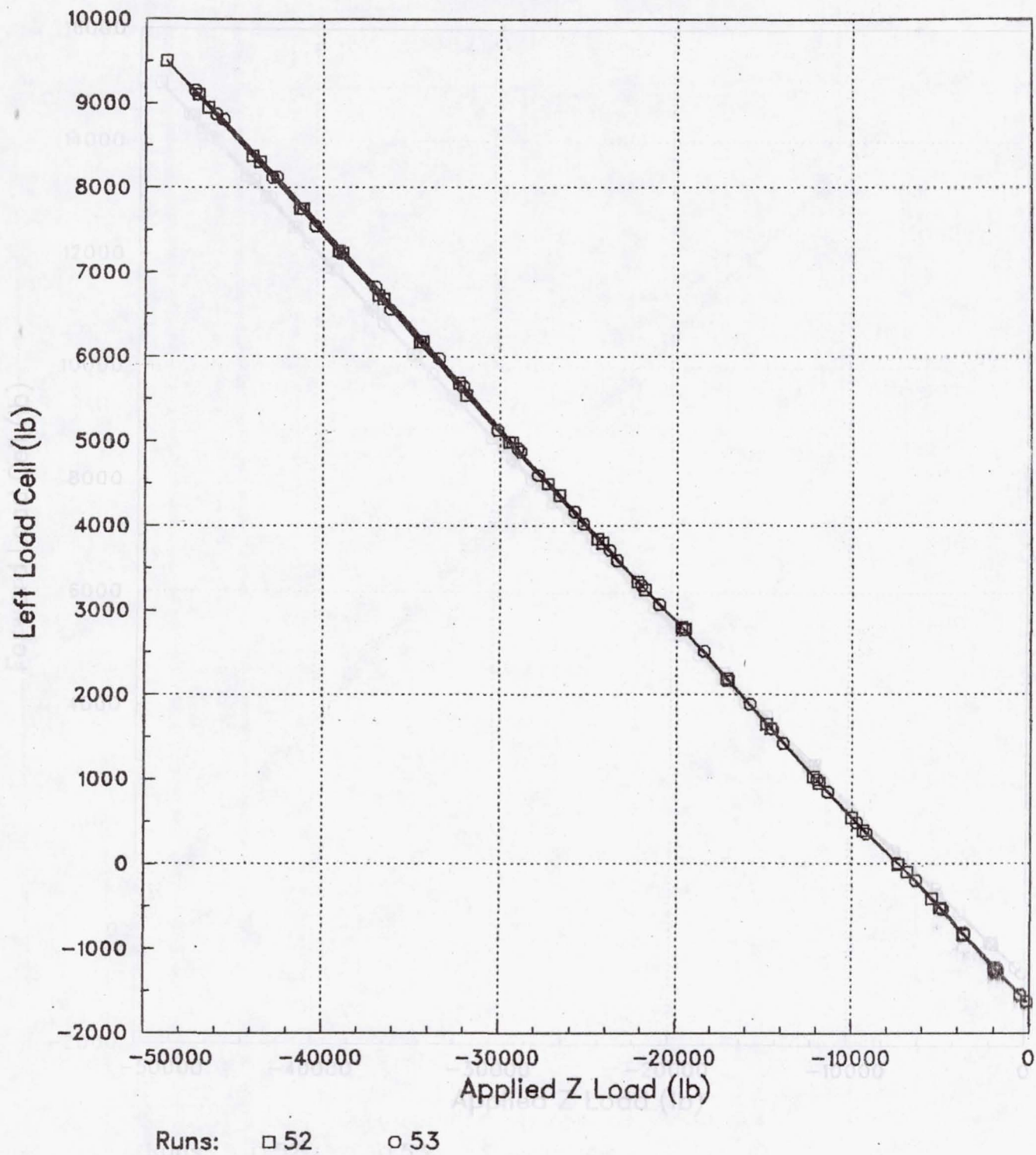
Runs: □ 52 ○ 53

RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Loads: None

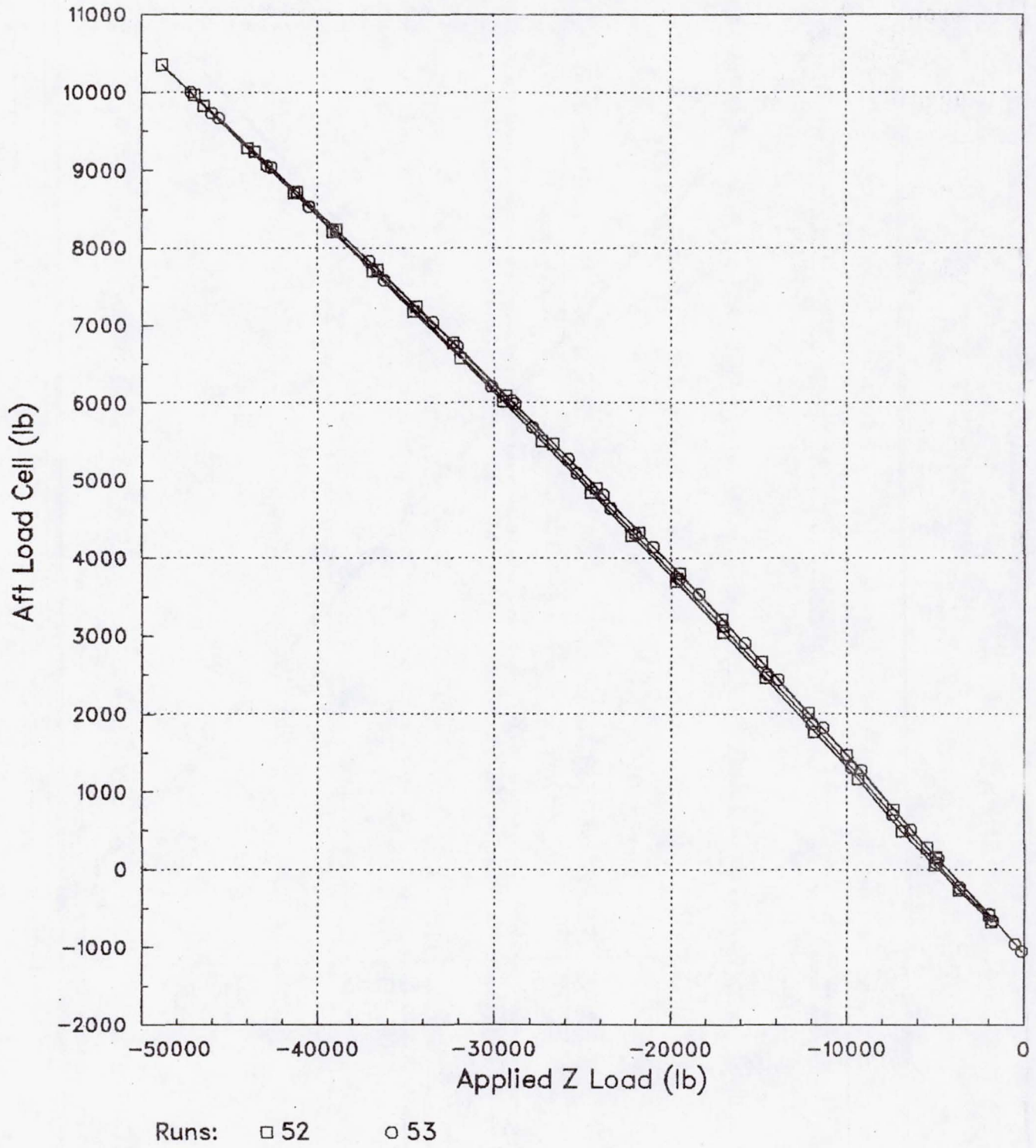


Applied Z Load
Constant Loads: None

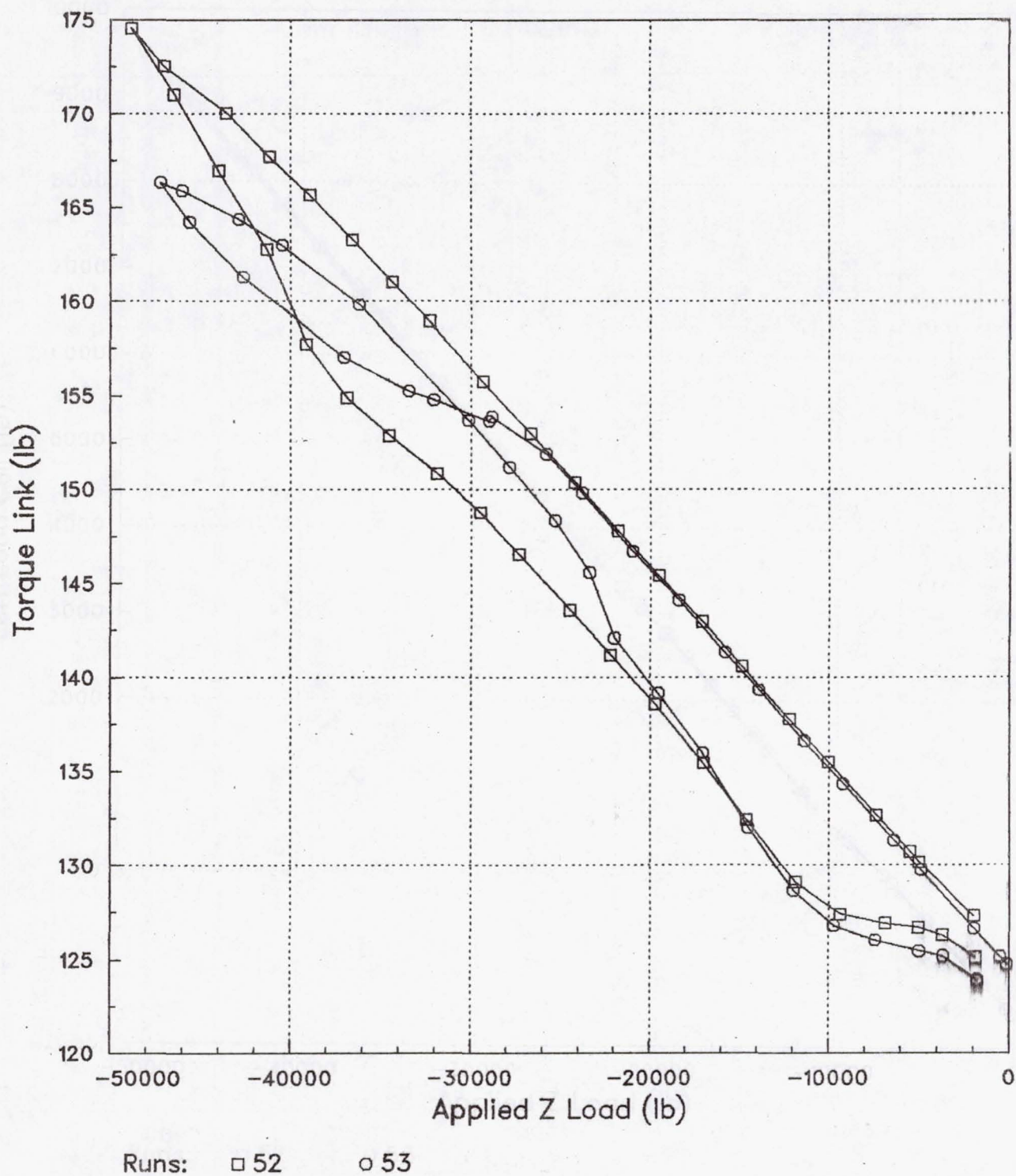


RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Loads: None

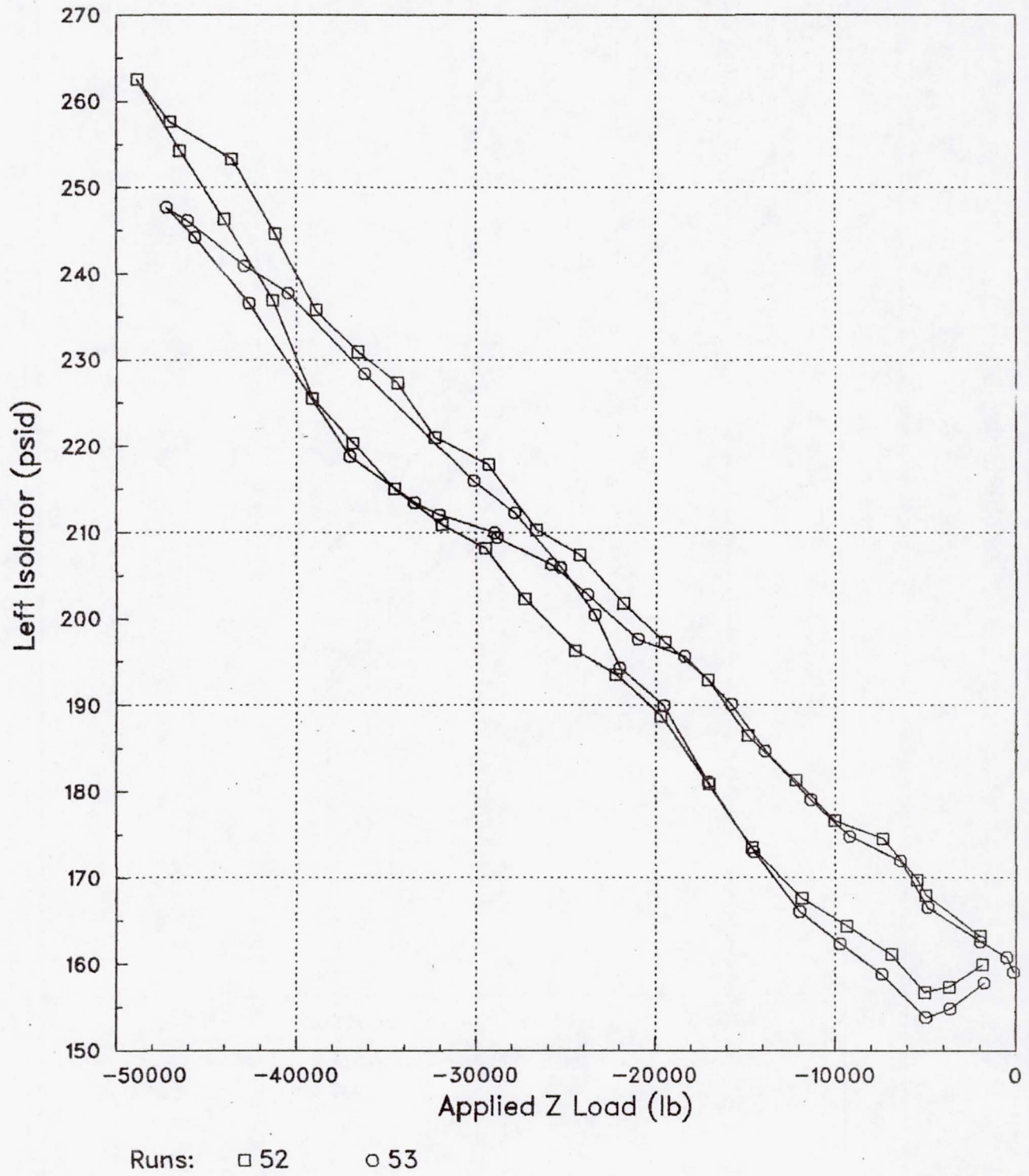


Applied Z Load
Constant Loads: None



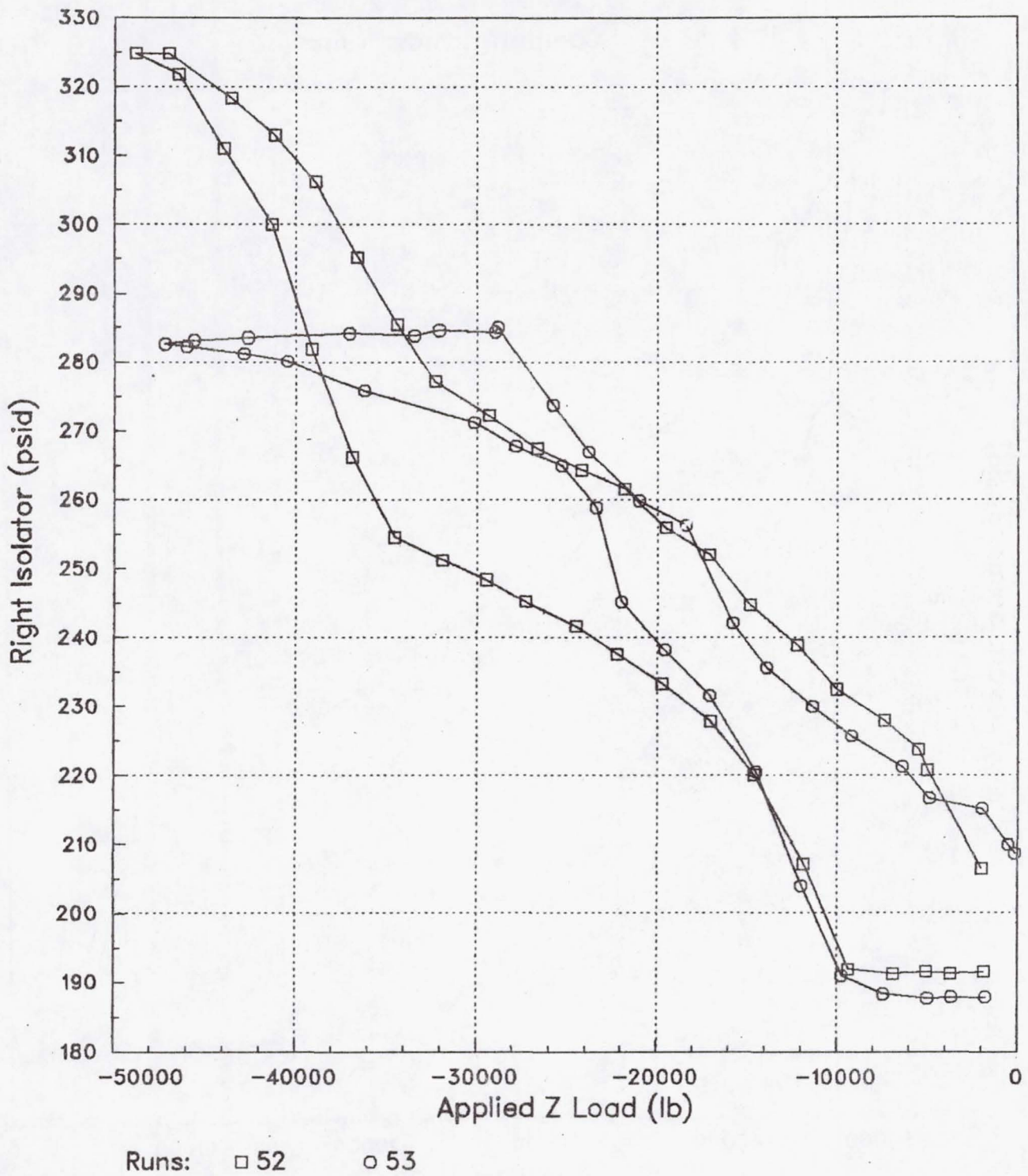
RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Loads: None



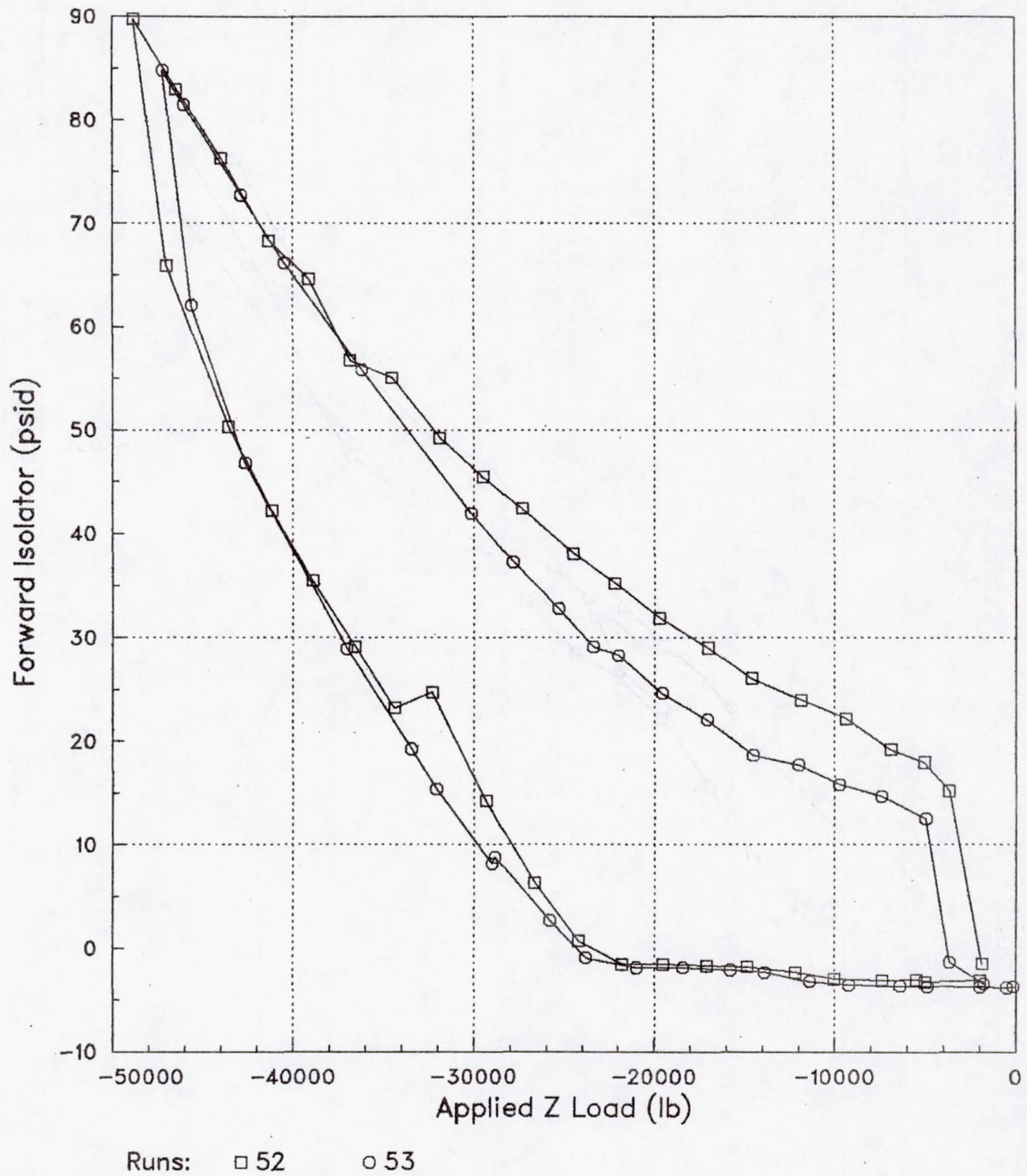
Applied Z Load

Constant Loads: None

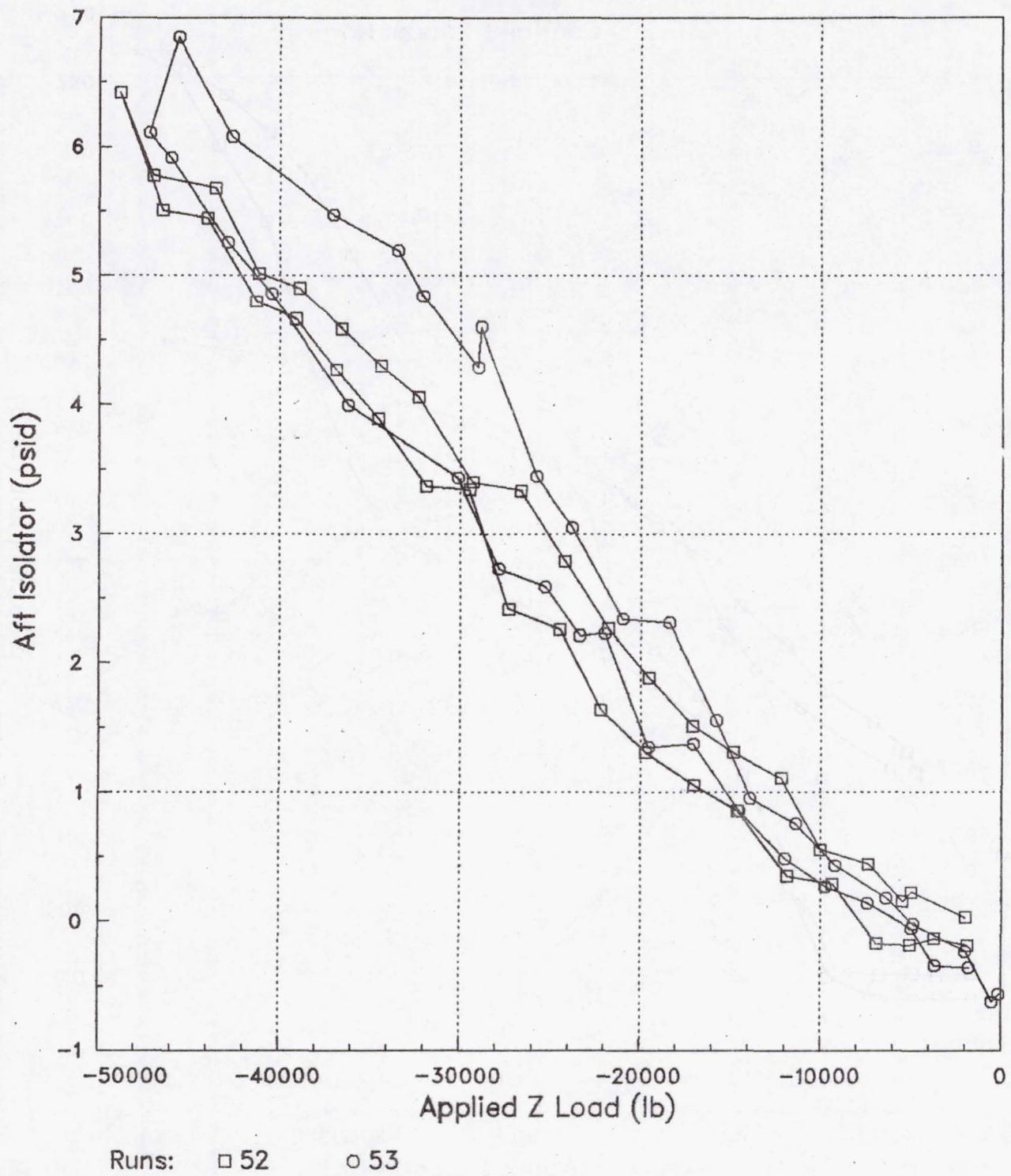


RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Loads: None

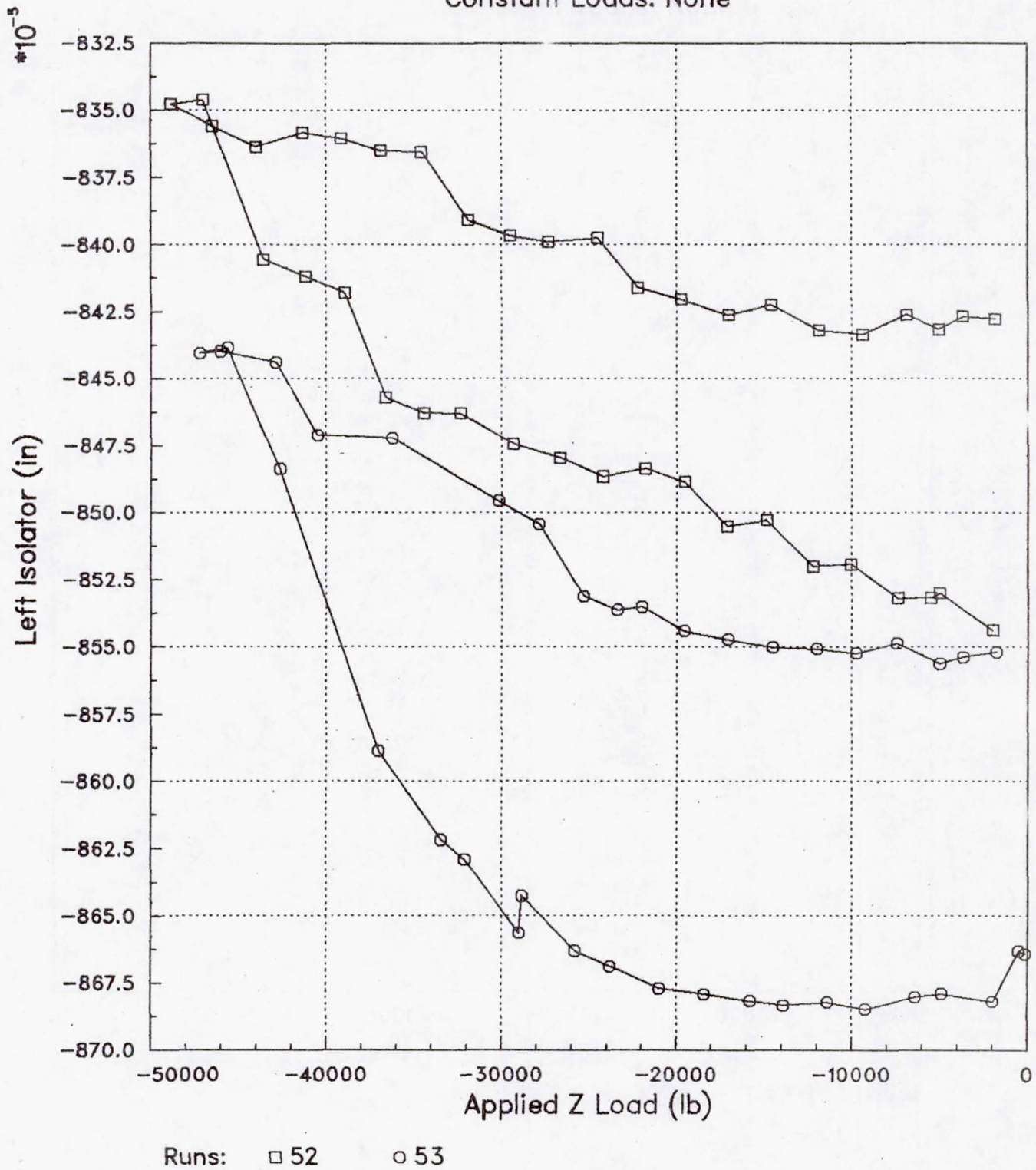


Applied Z Load
Constant Loads: None

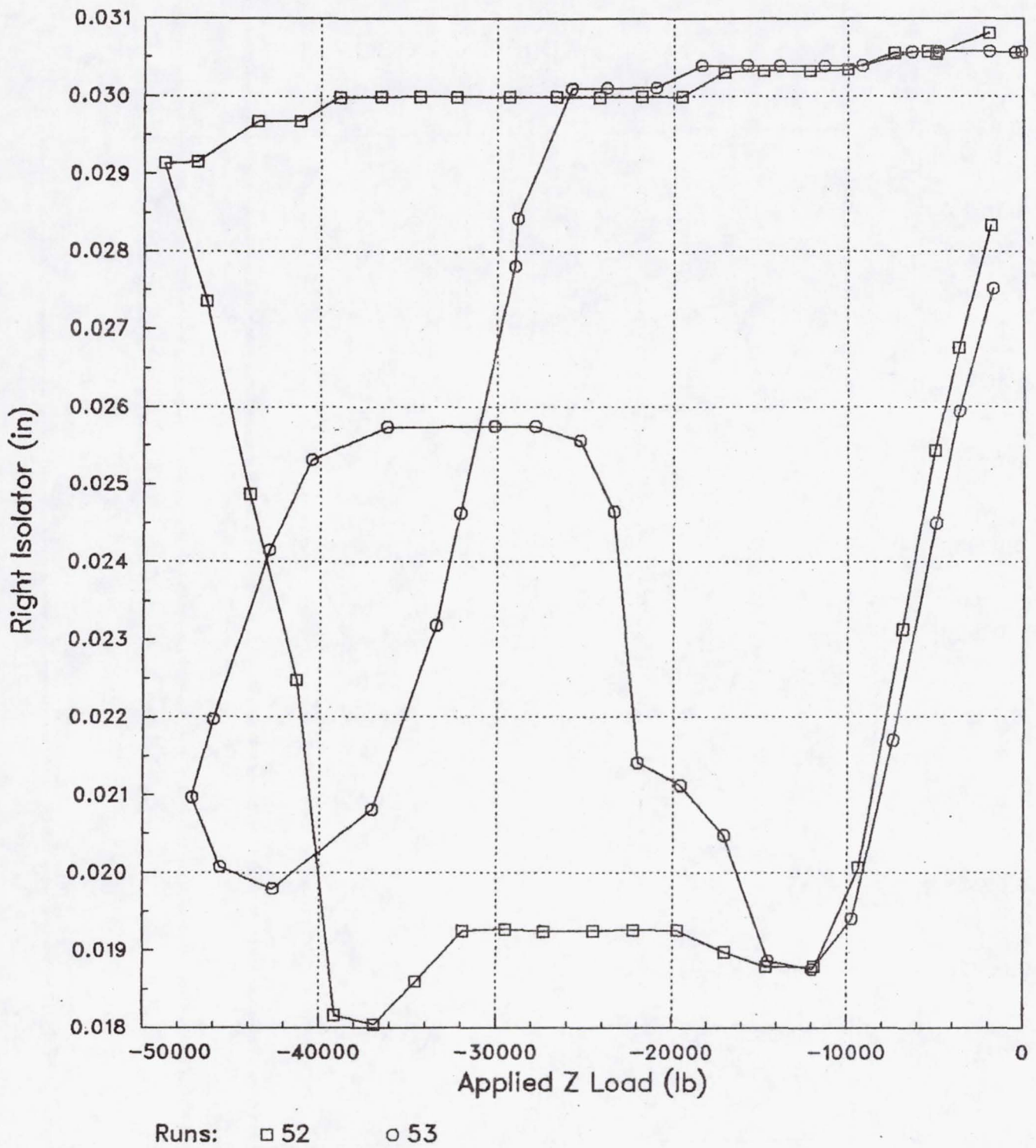


RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Loads: None

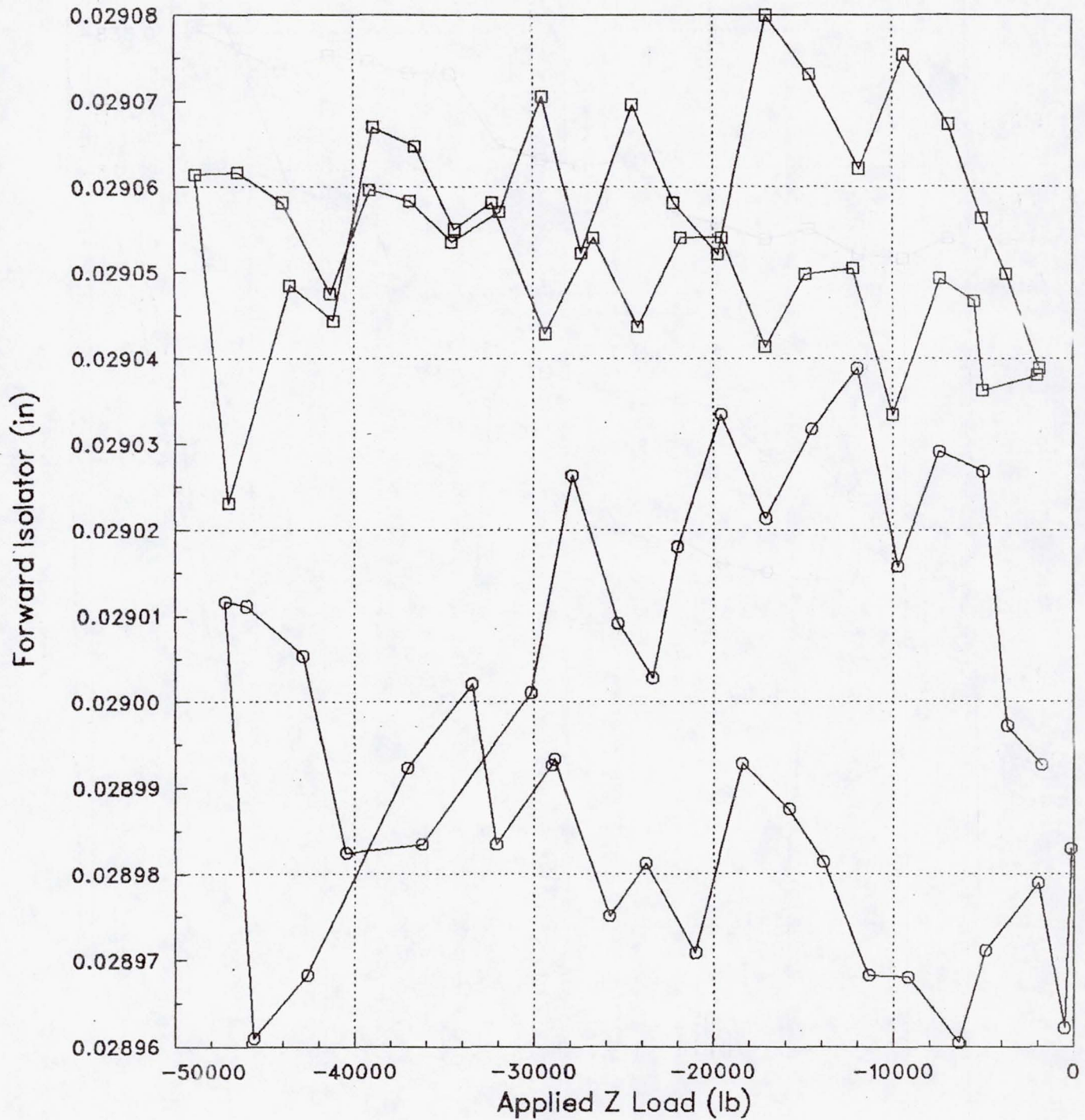


Applied Z Load
Constant Loads: None



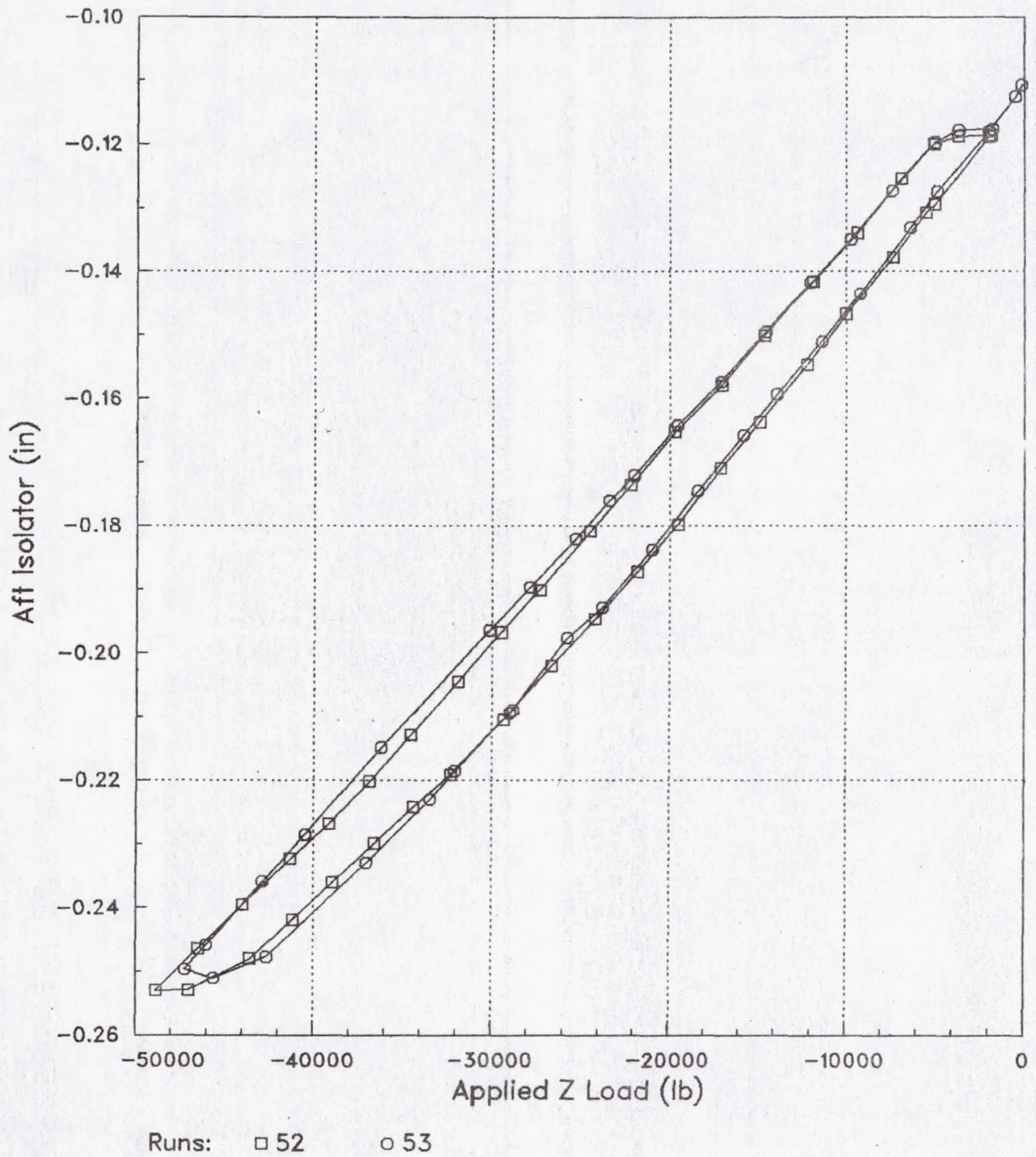
RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Loads: None



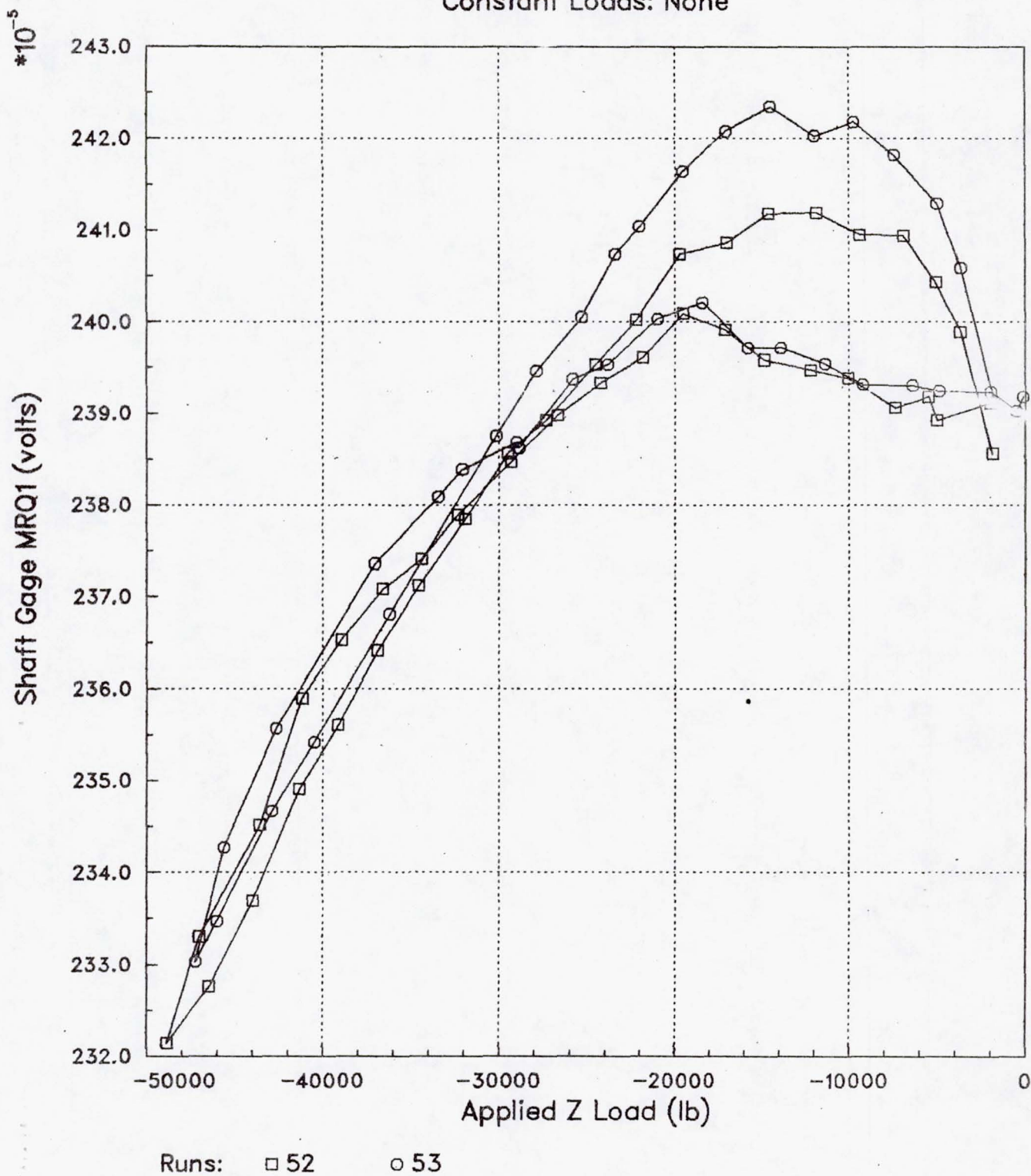
Runs: □ 52 ○ 53

Applied Z Load
Constant Loads: None



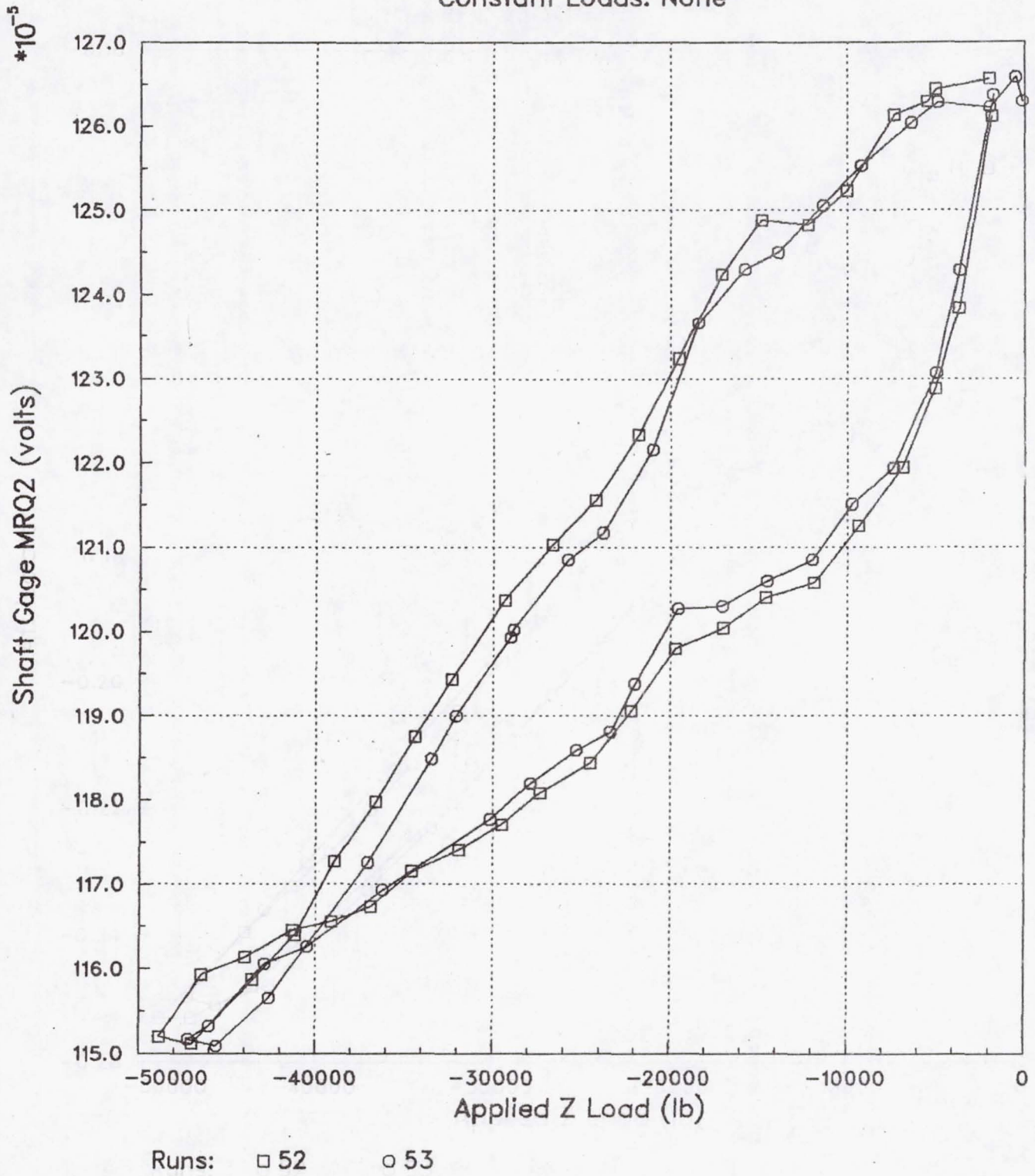
RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Loads: None



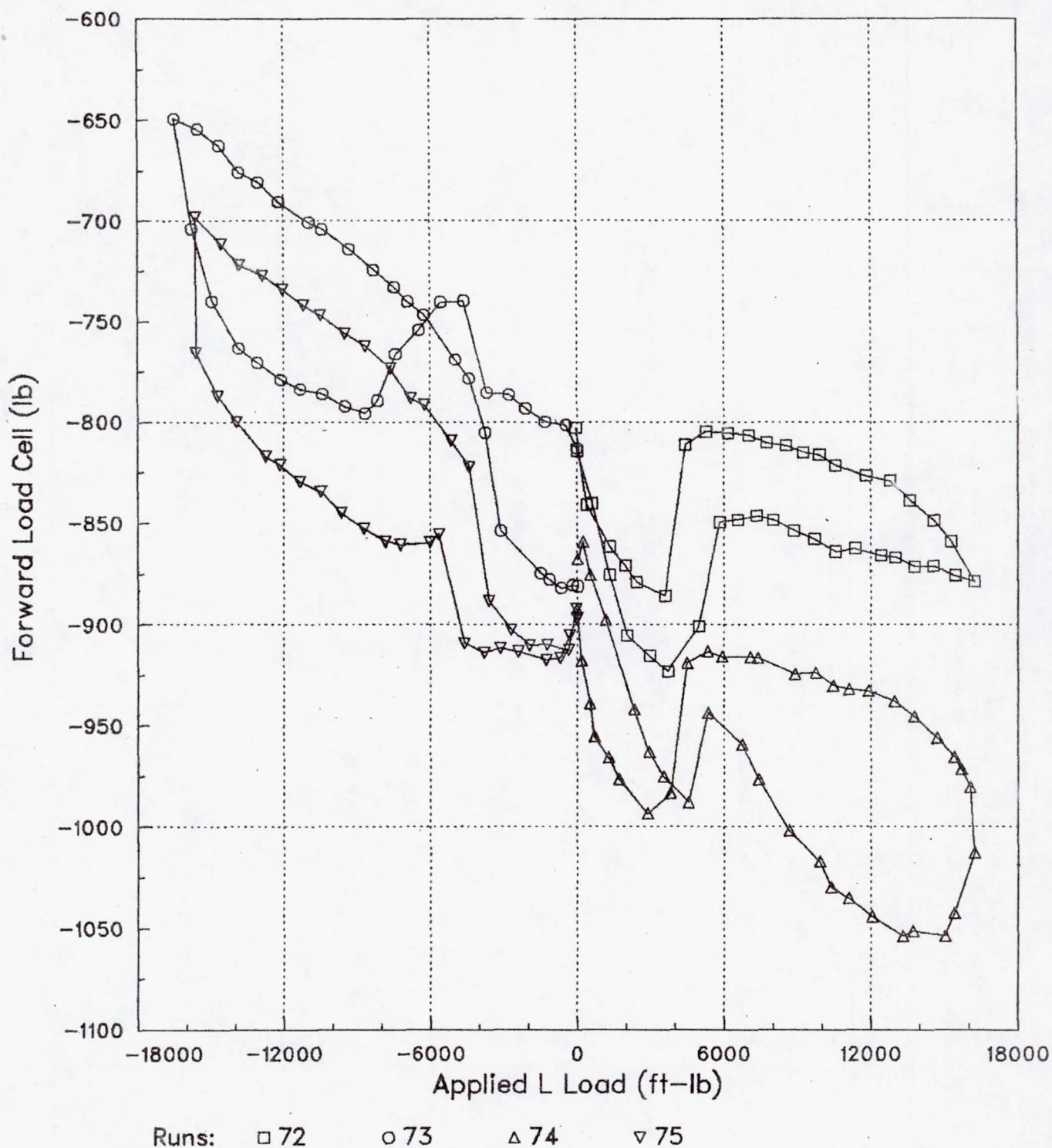
RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Loads: None



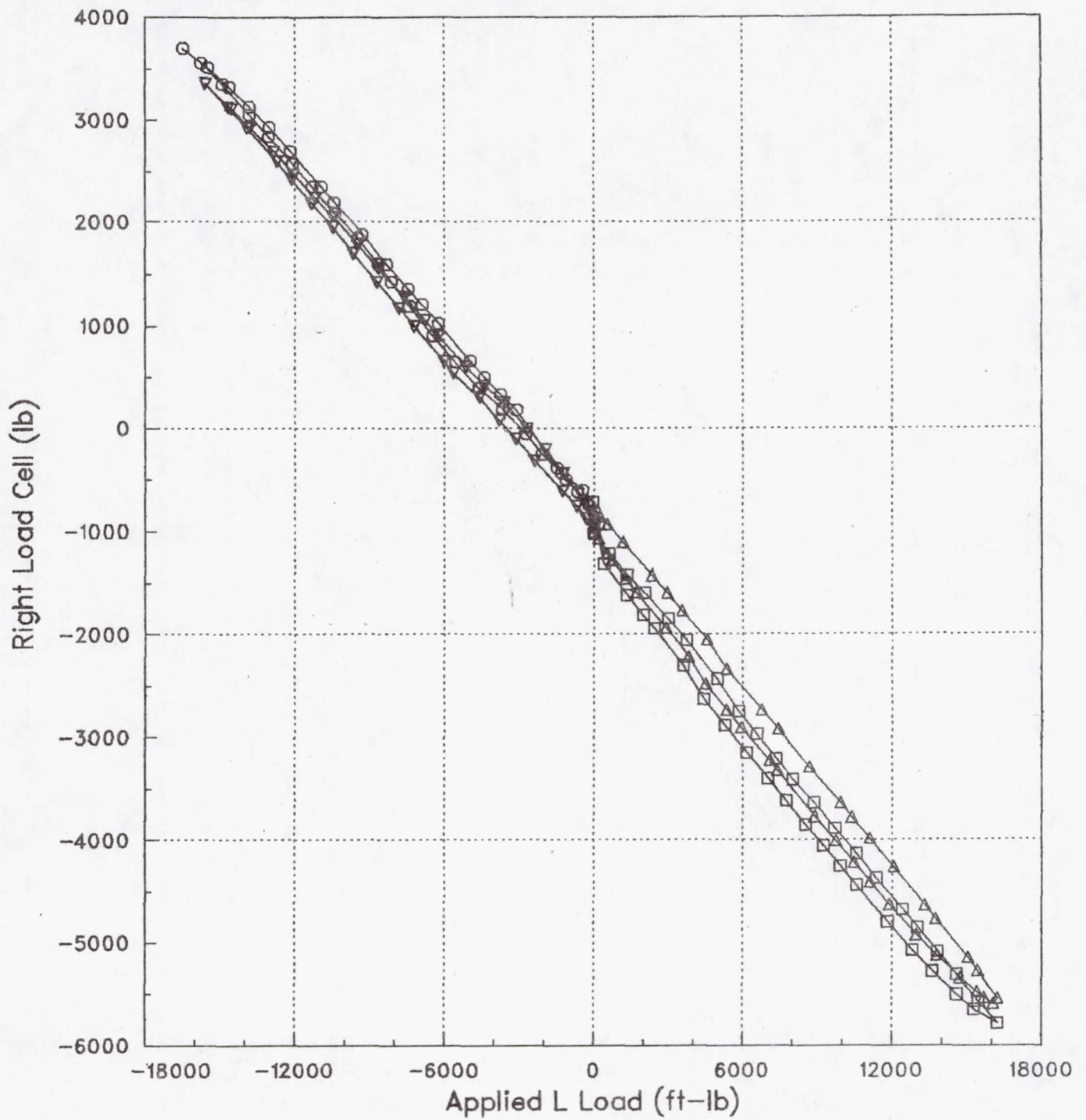
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



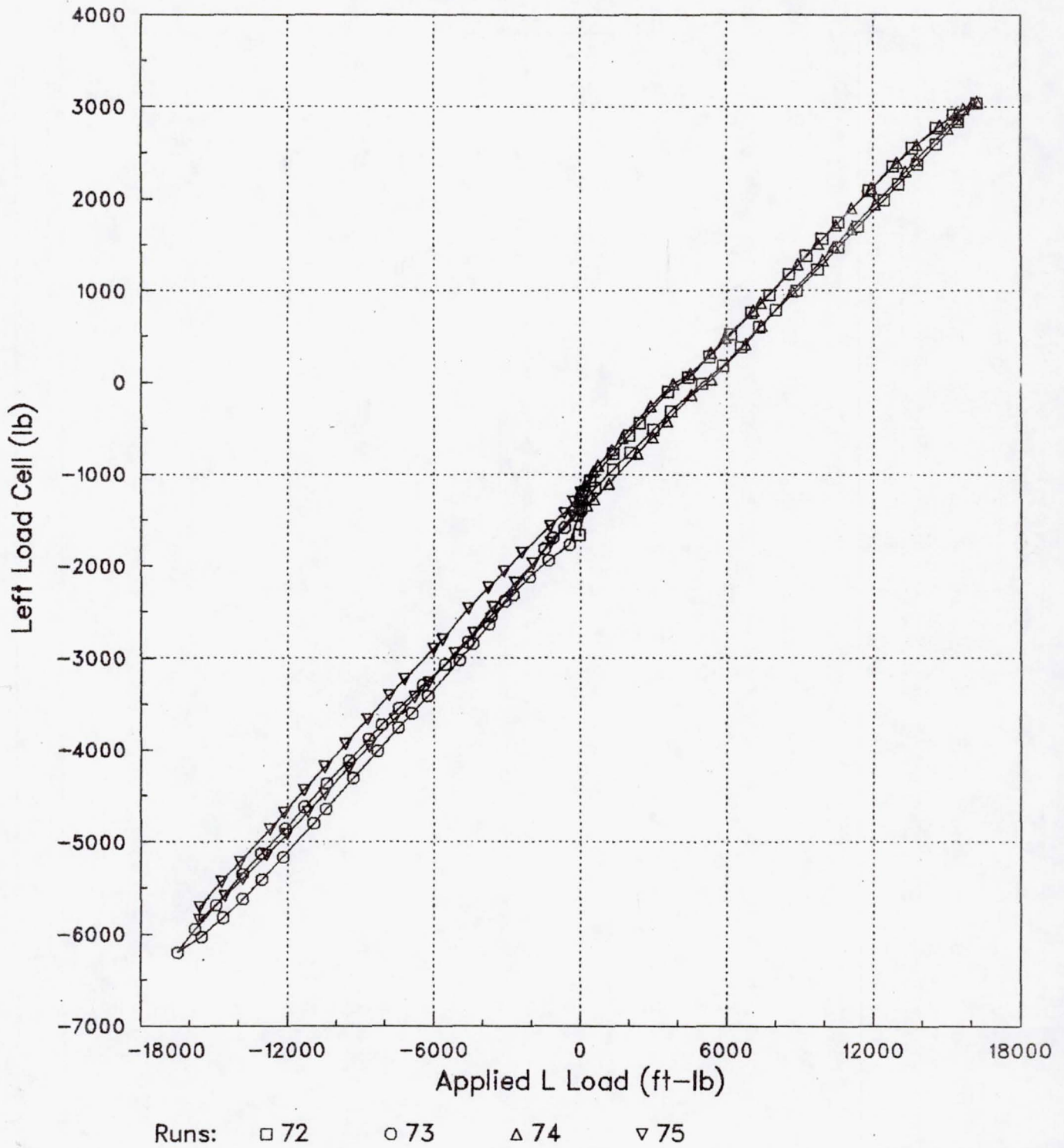
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



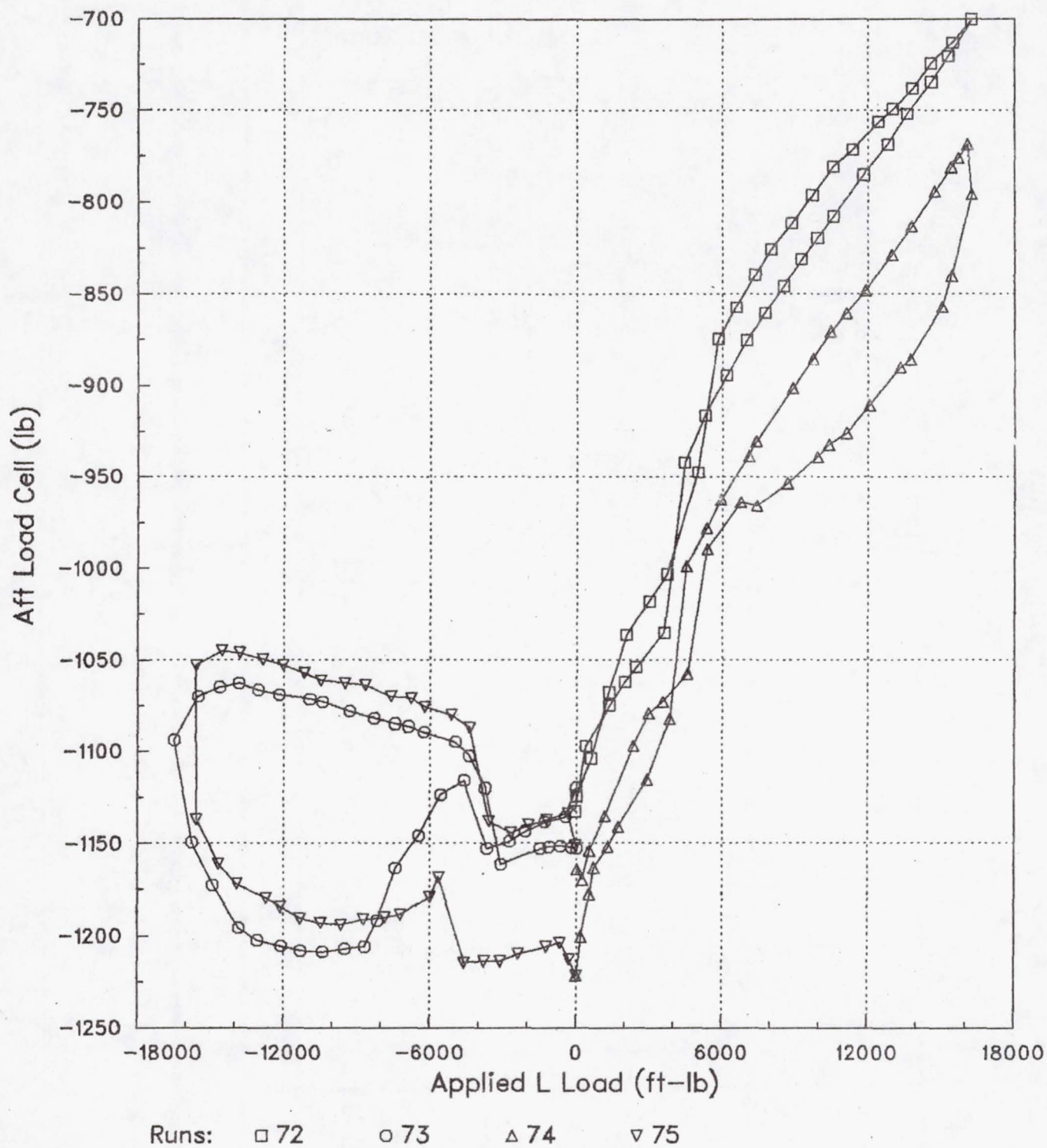
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



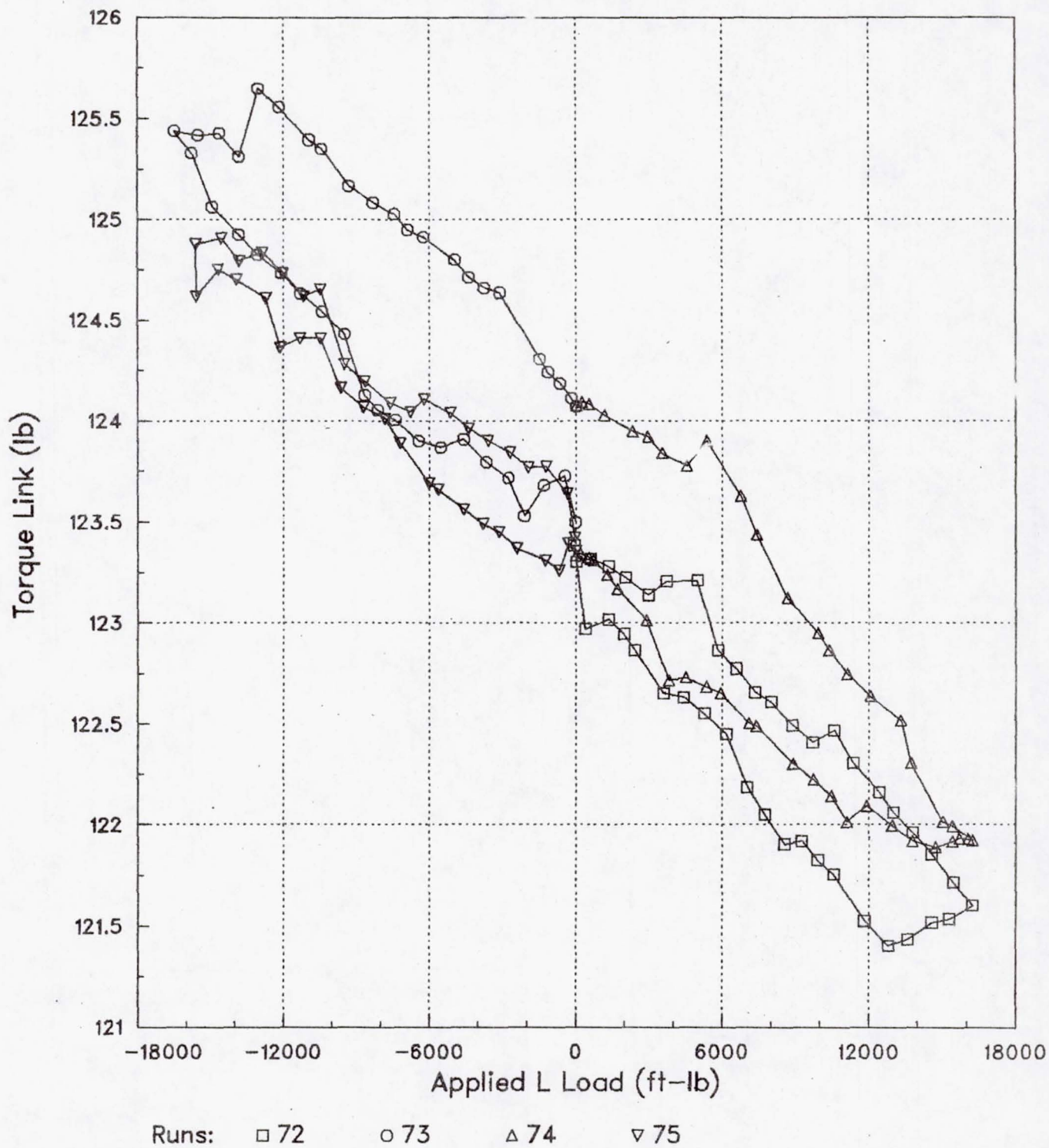
Applied L Load

Constant Loads: None



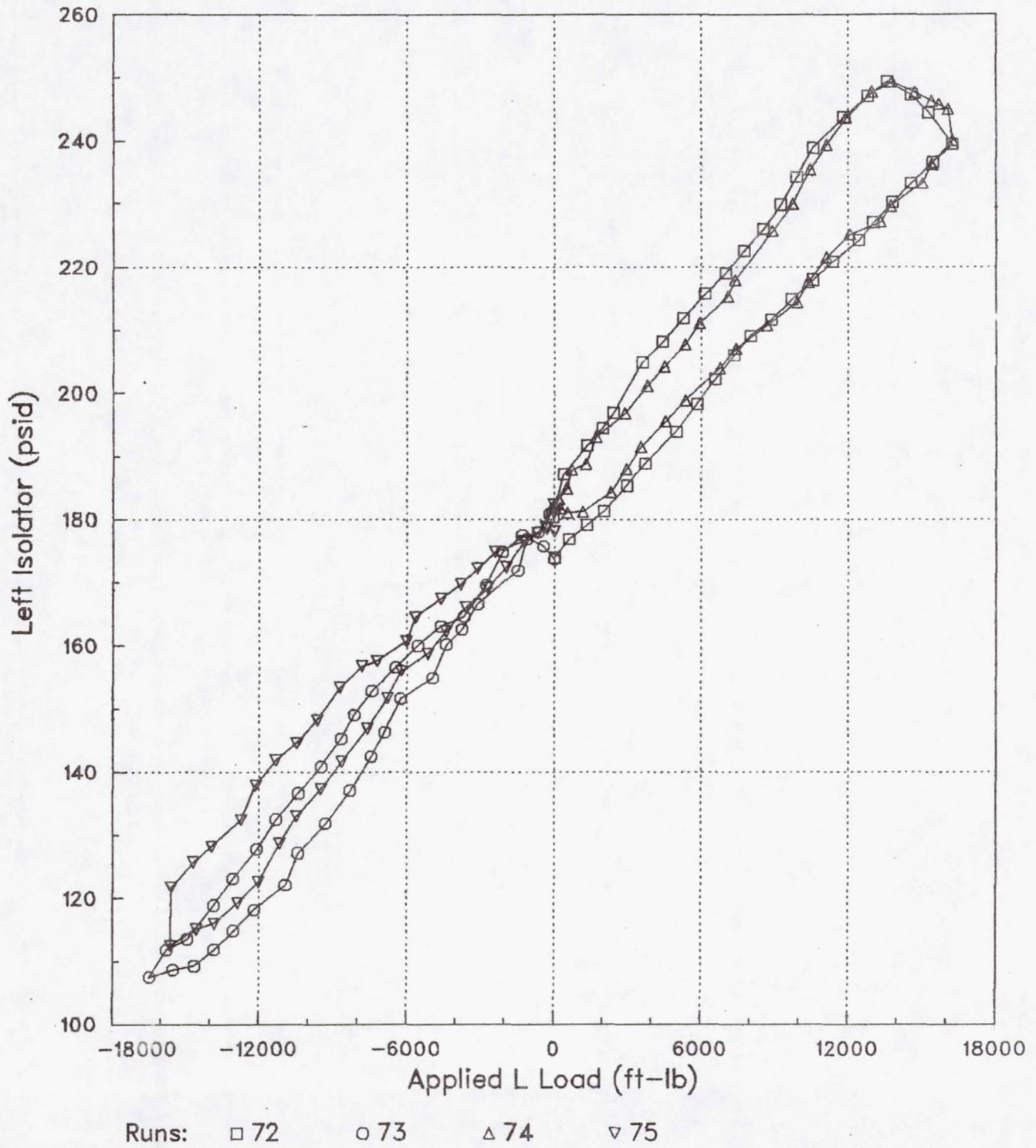
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



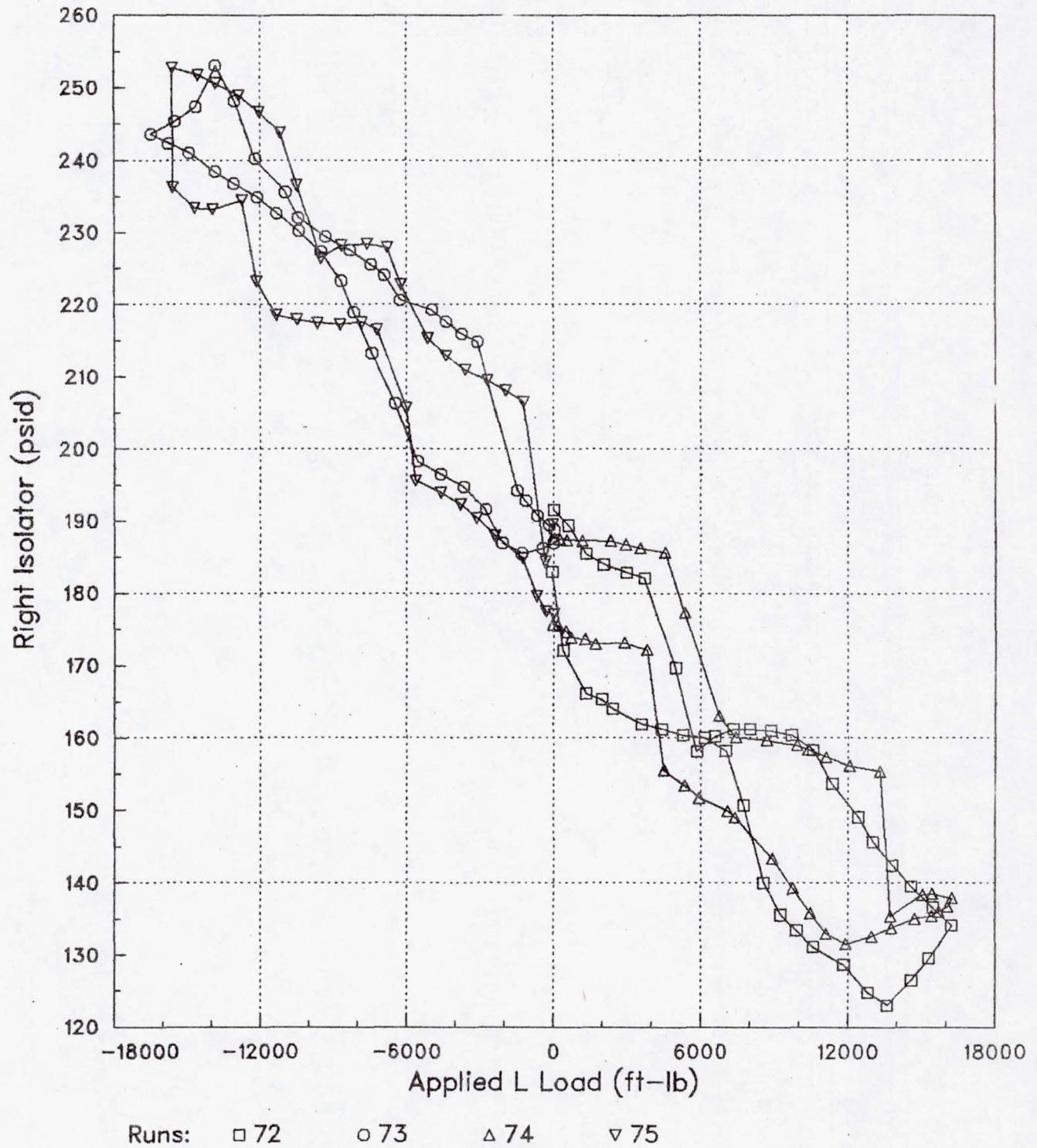
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



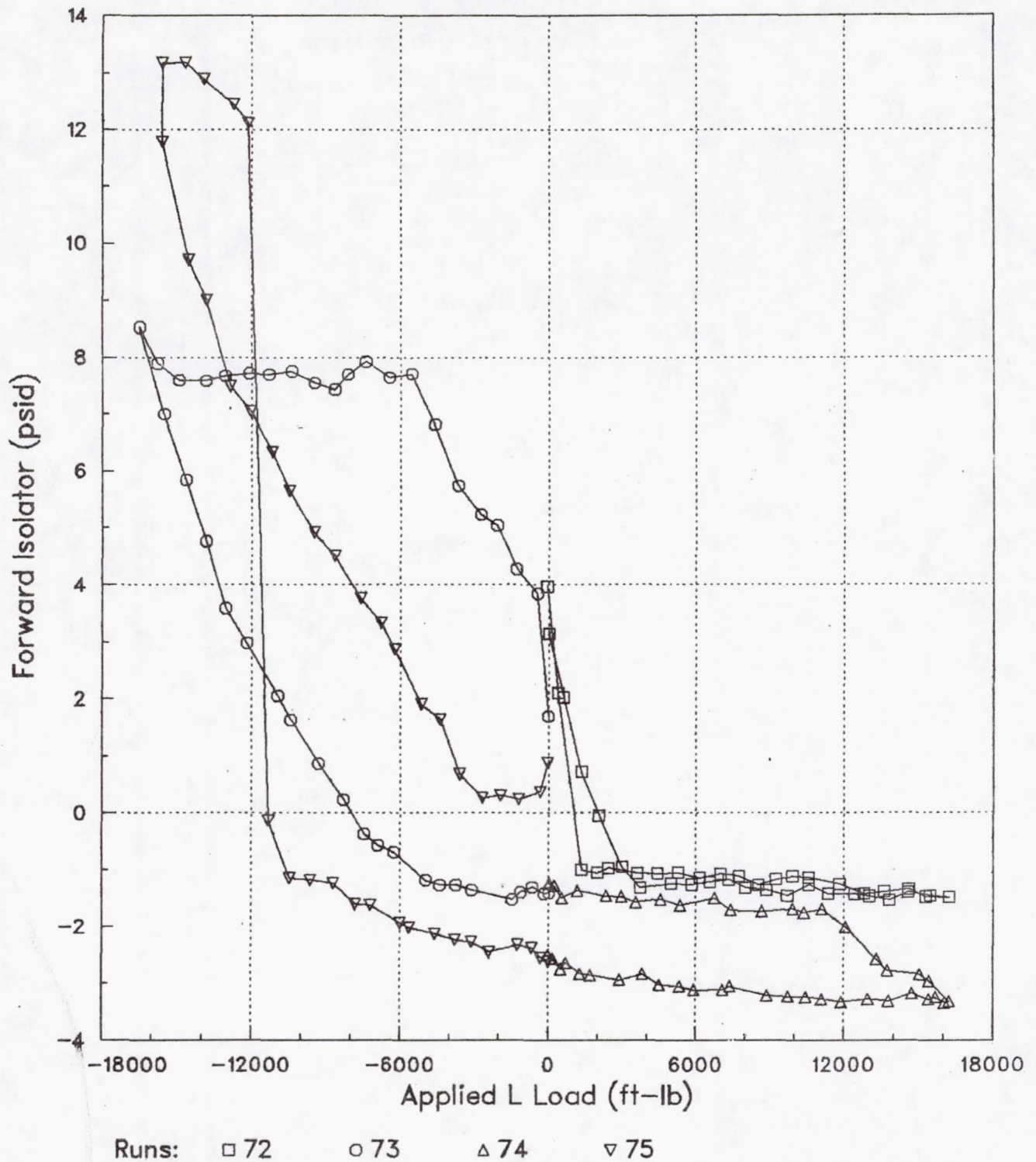
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



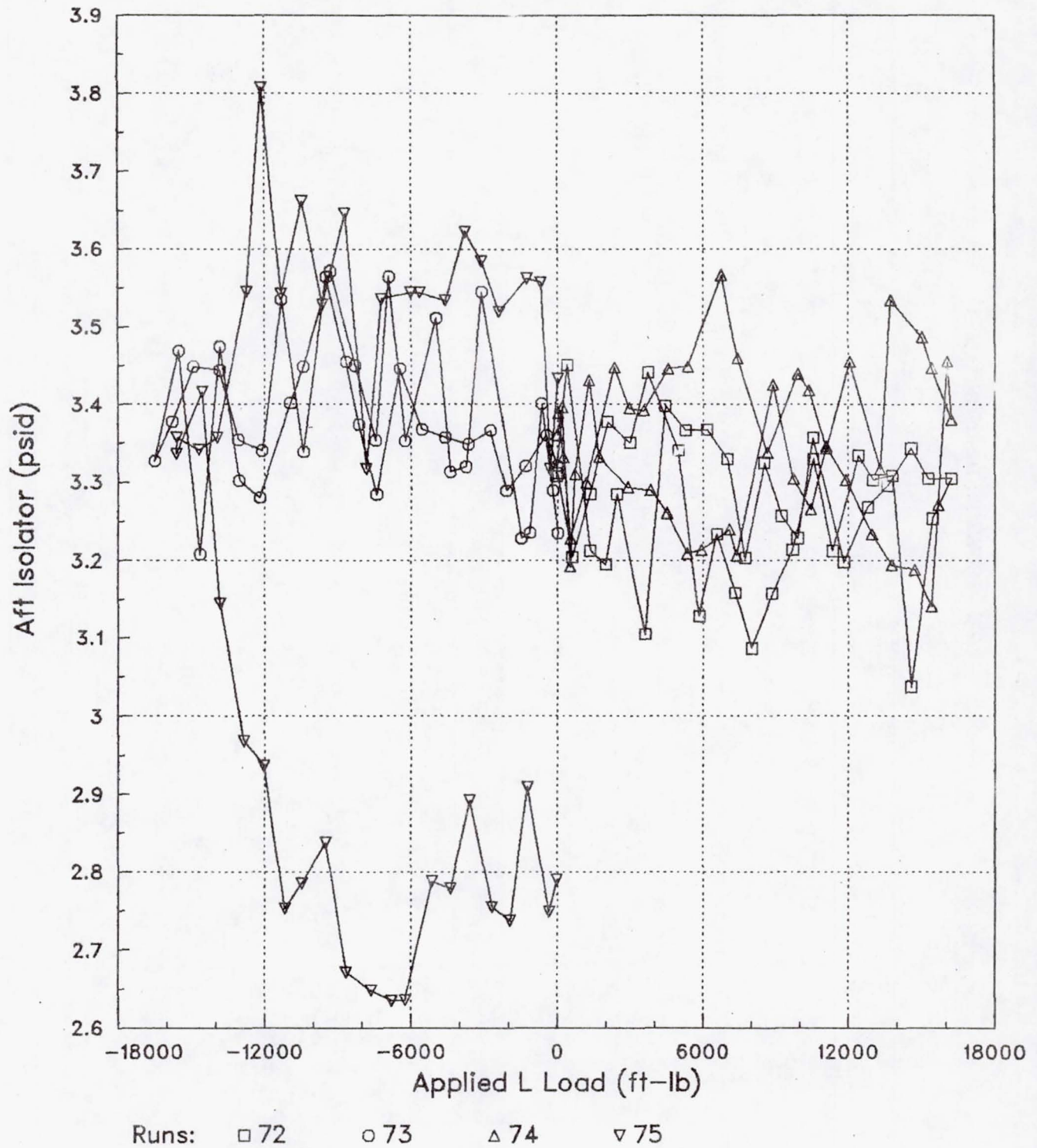
Applied L Load

Constant Loads: None



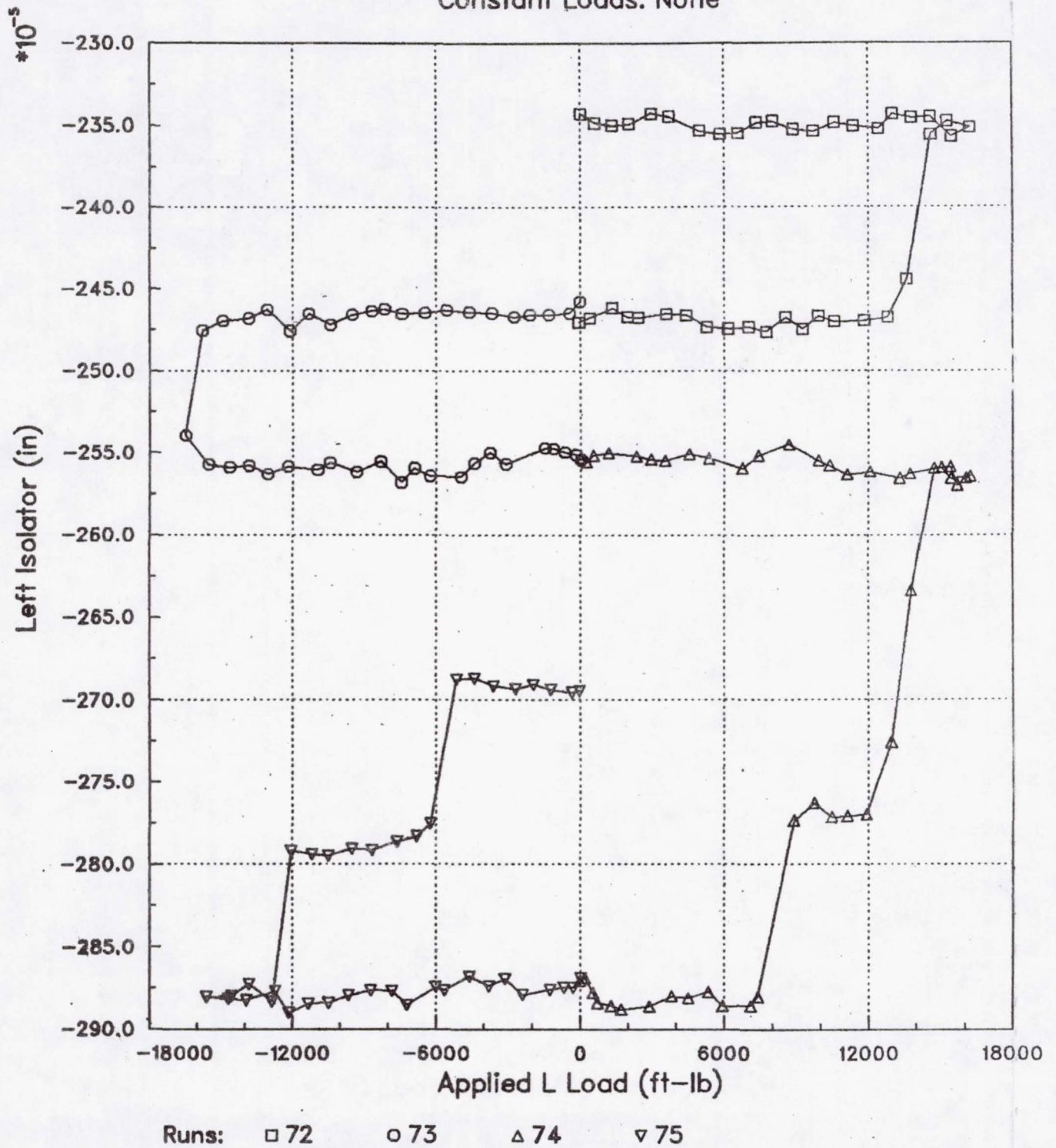
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



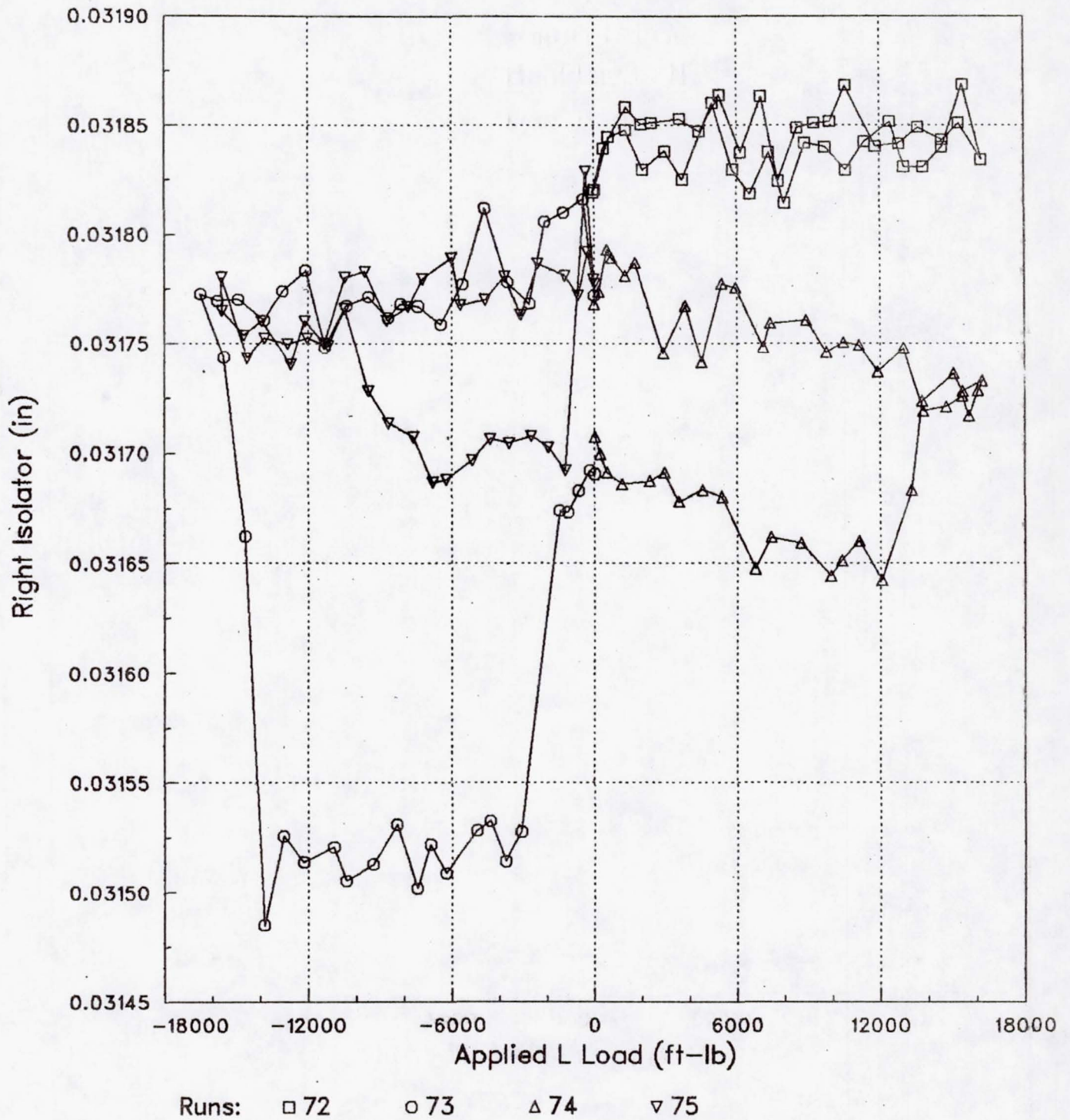
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



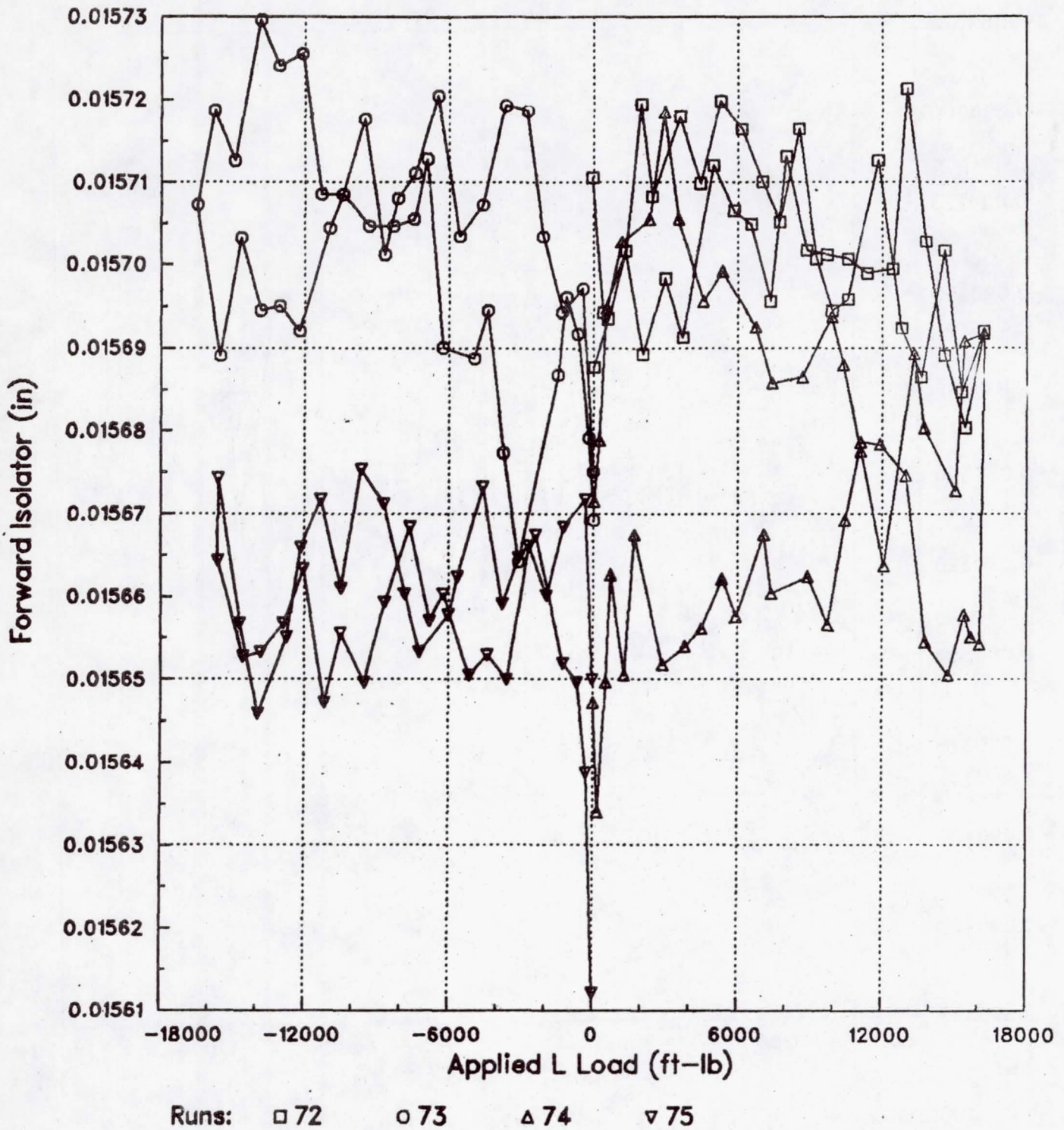
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



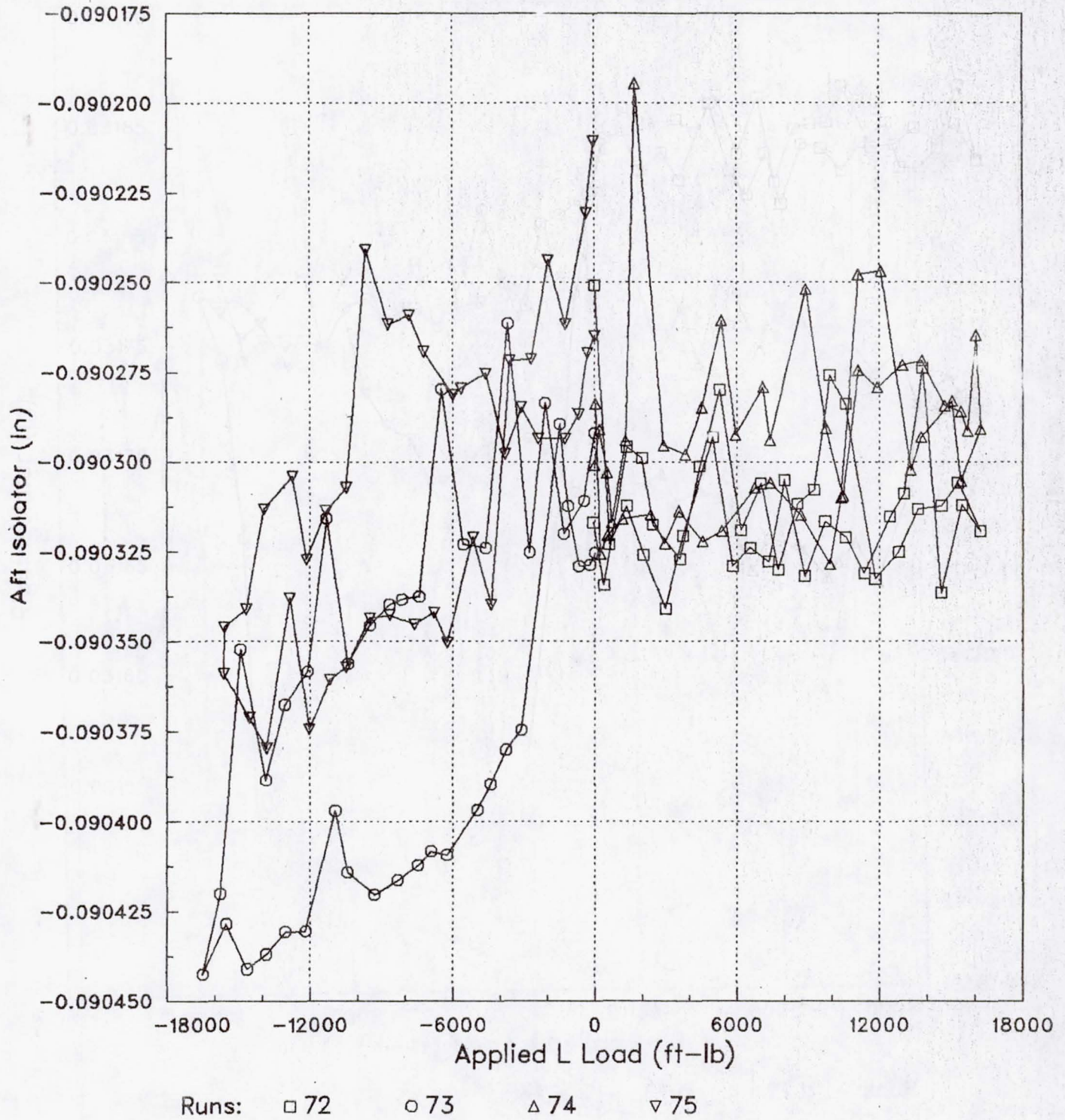
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



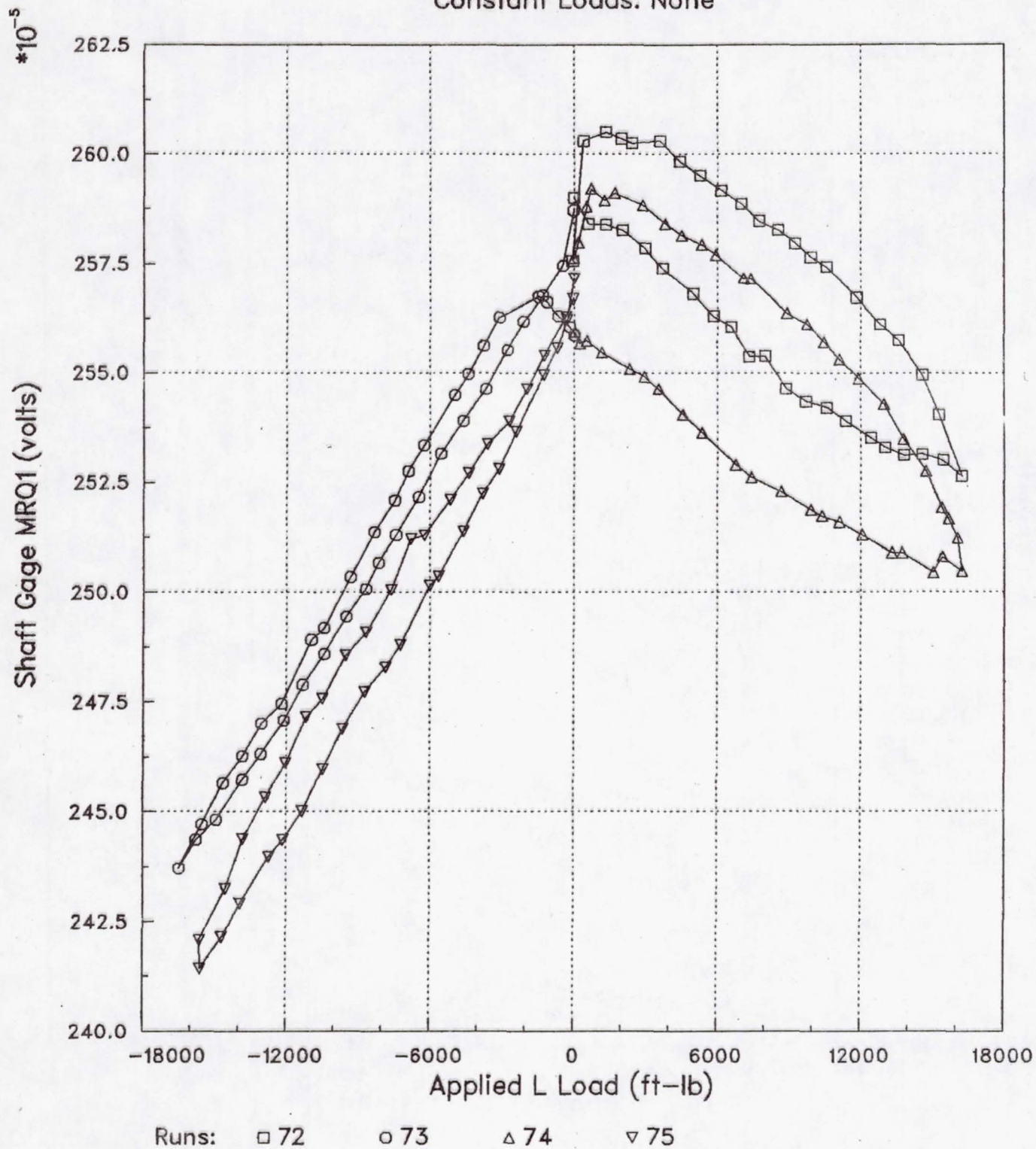
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



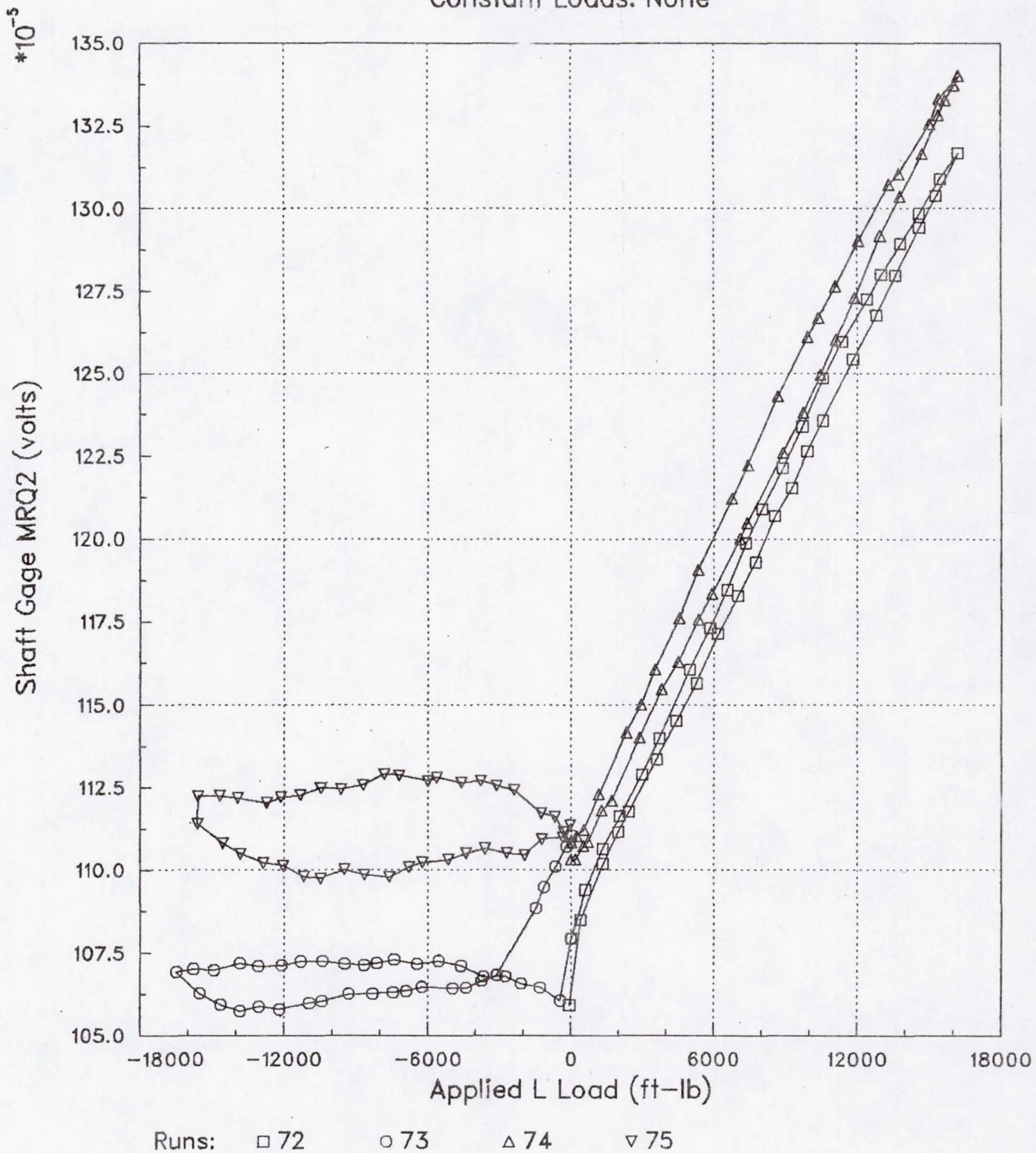
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



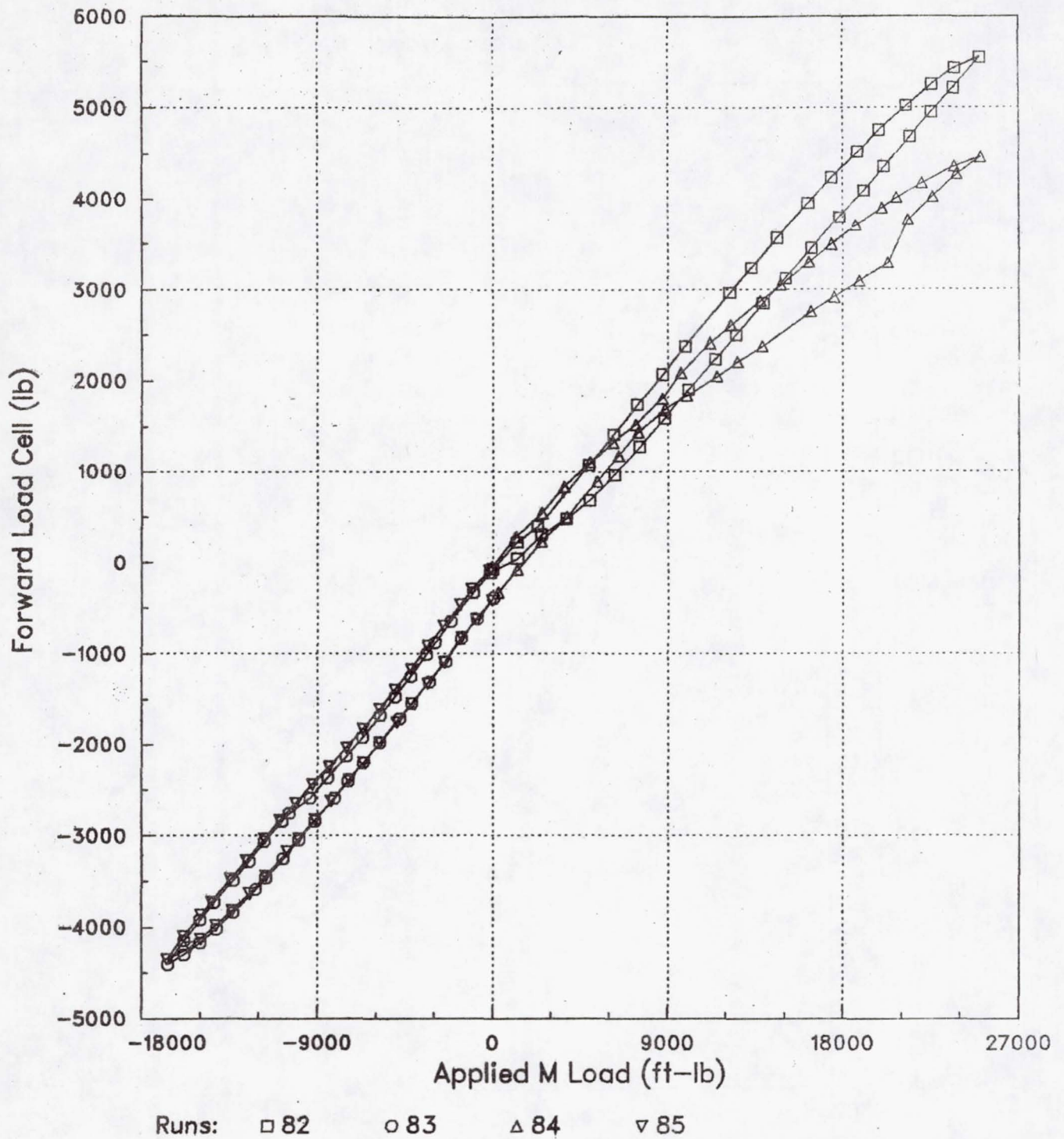
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: None



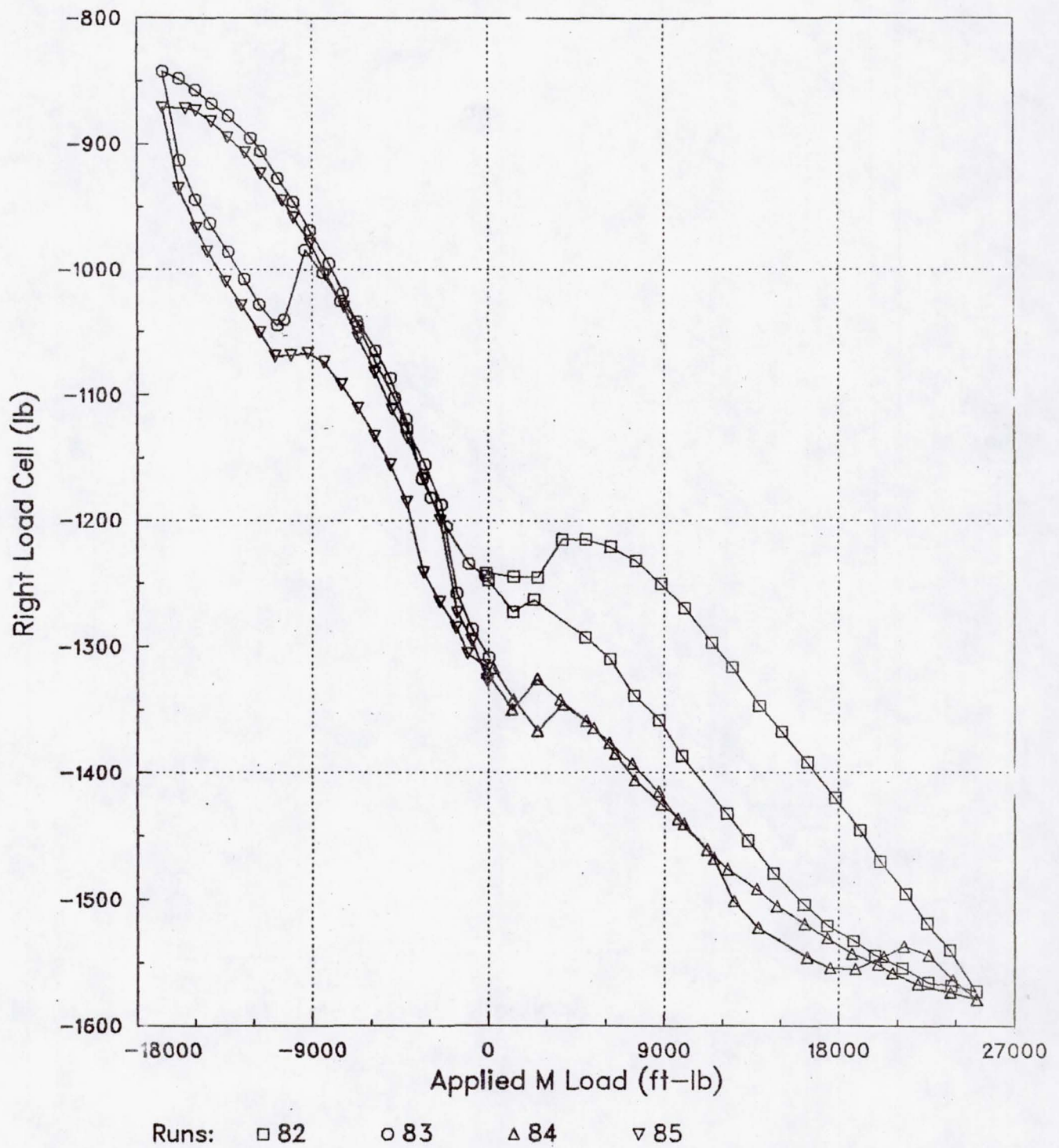
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



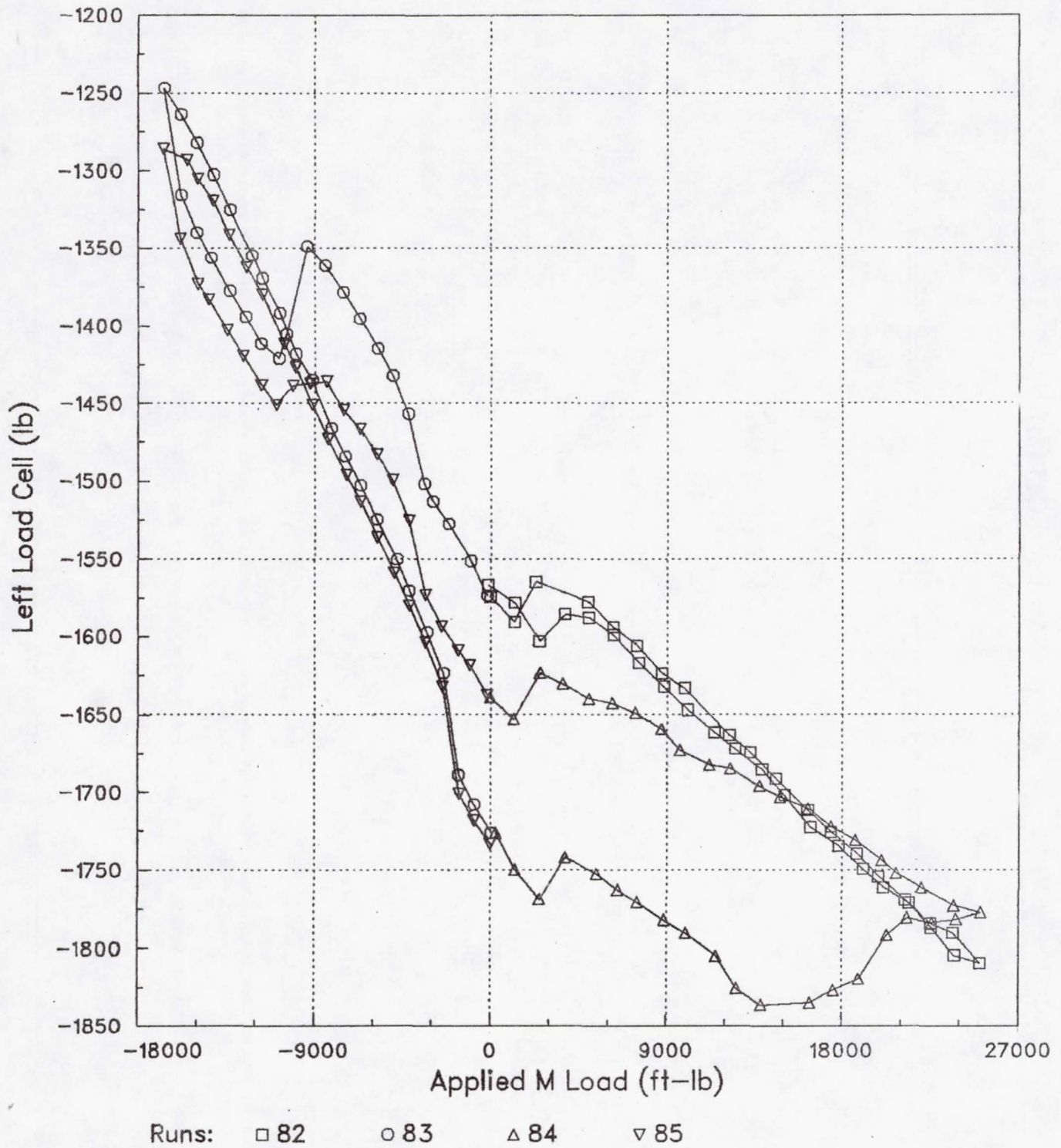
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



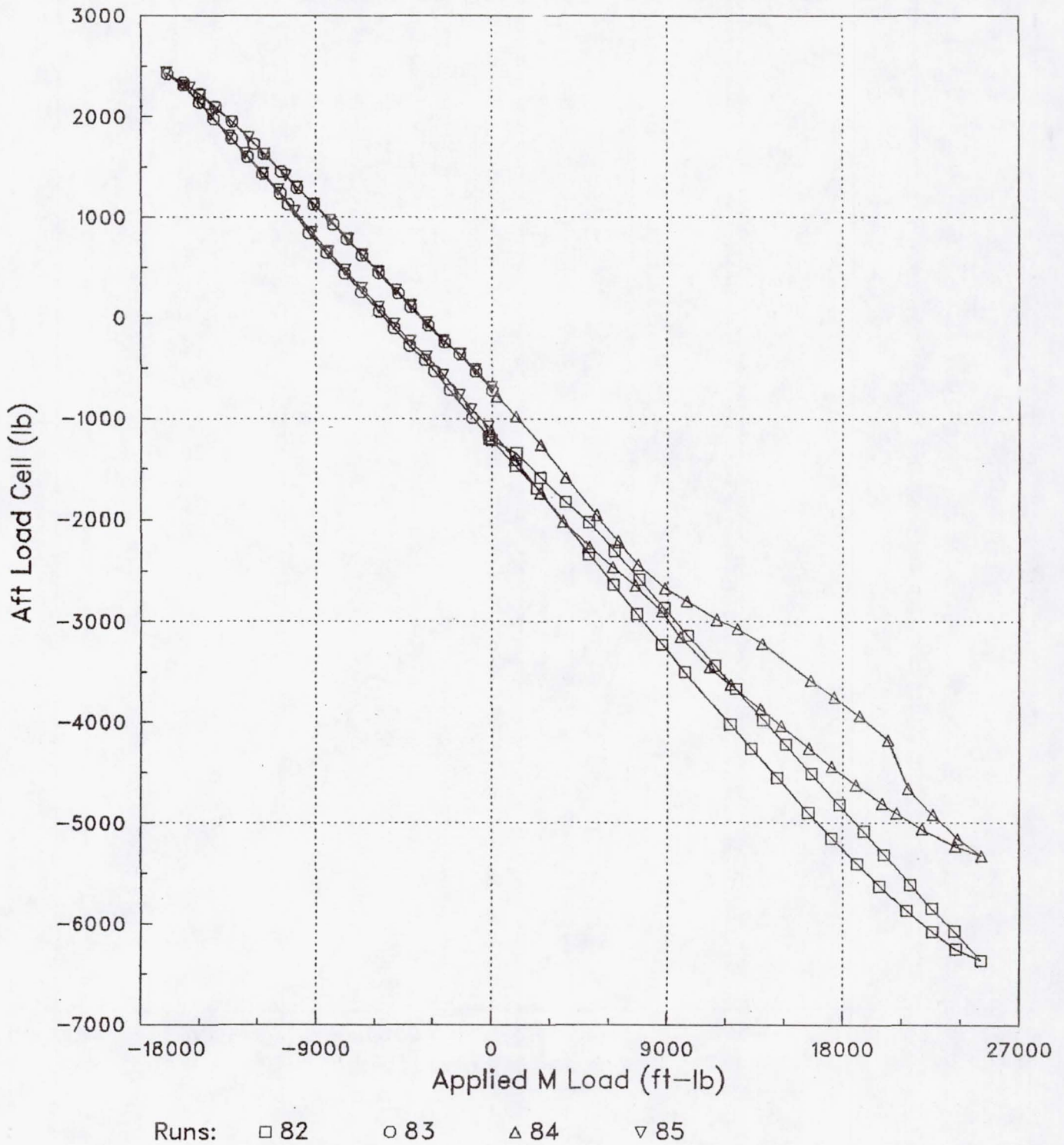
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



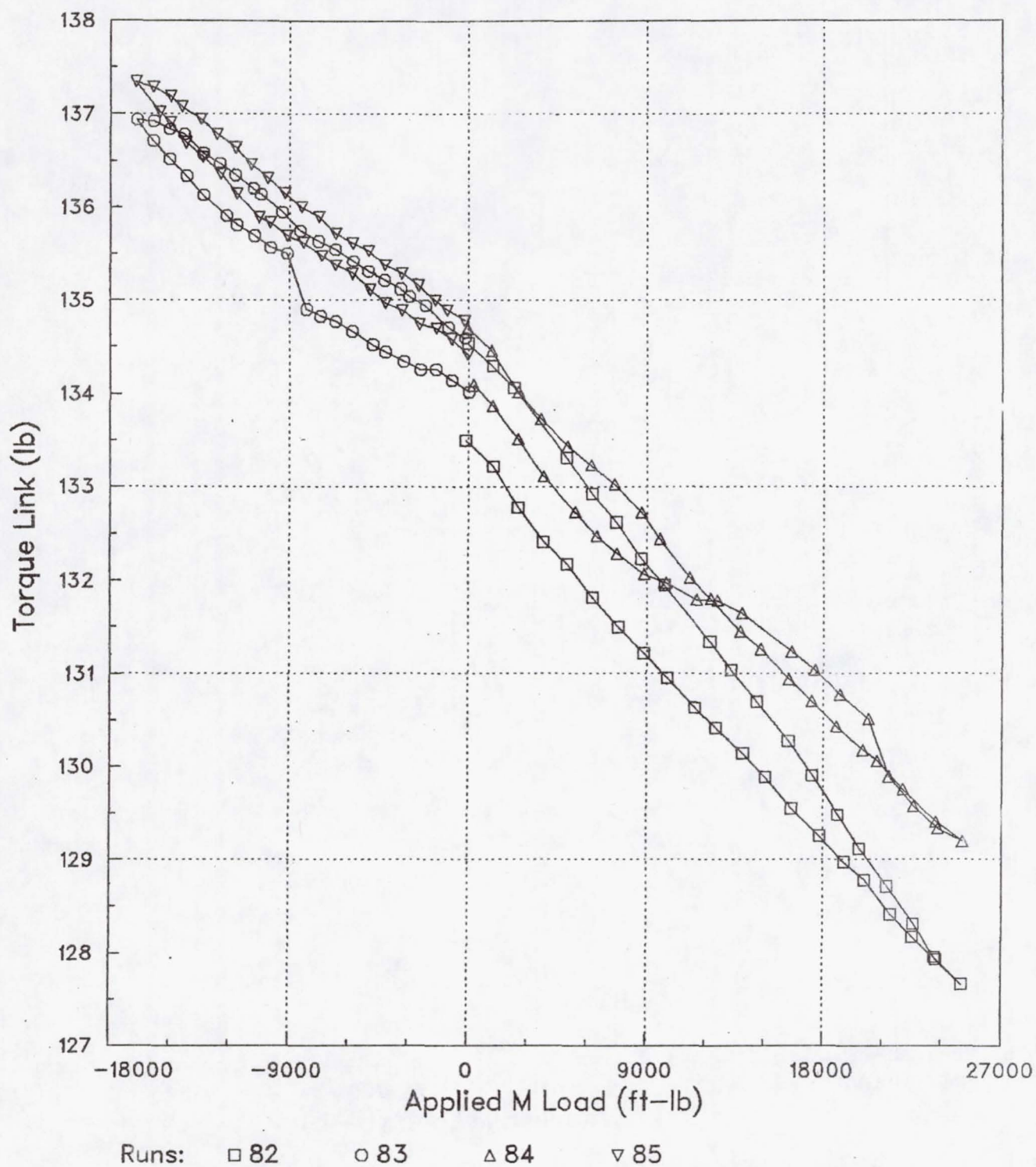
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



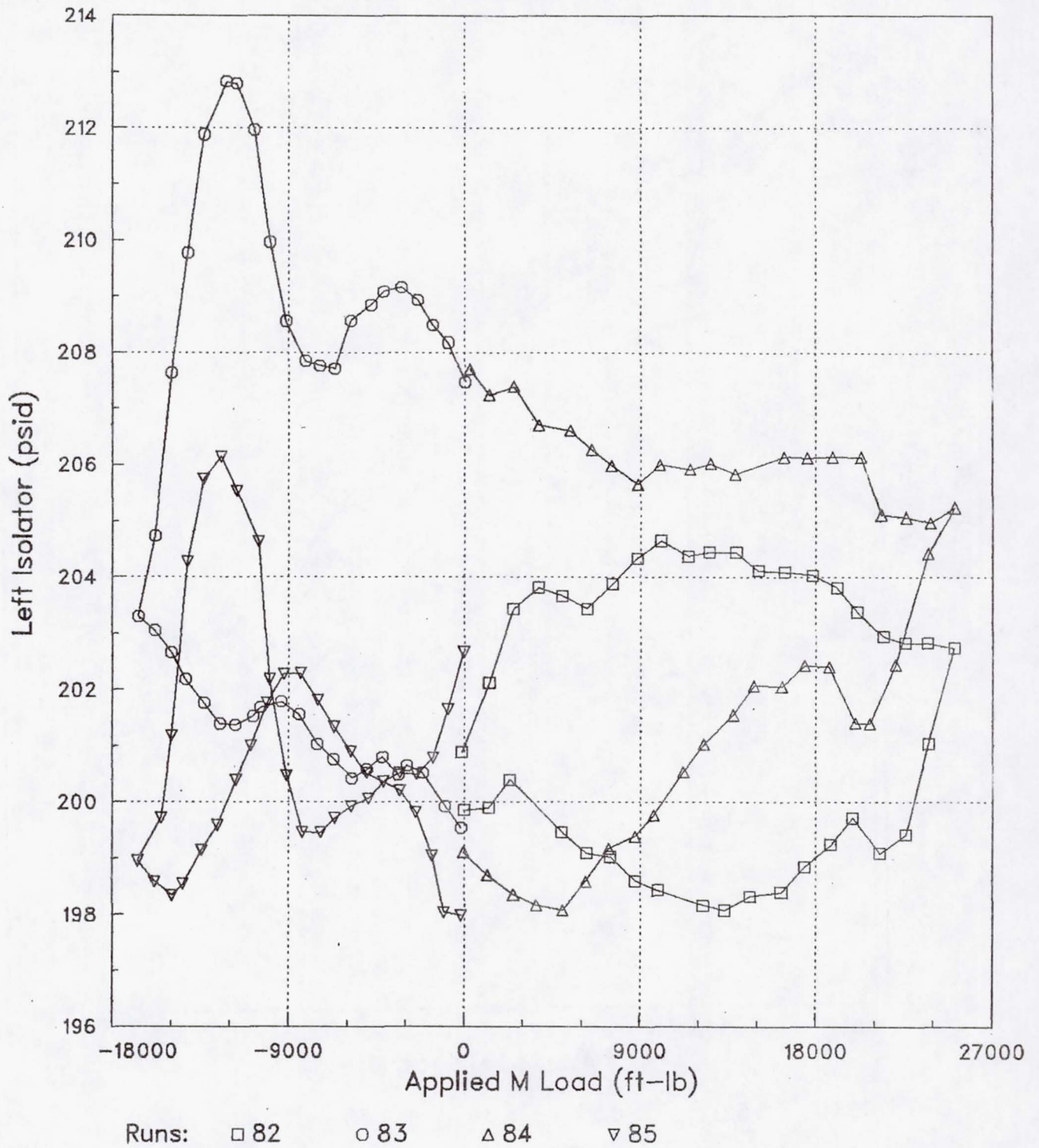
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



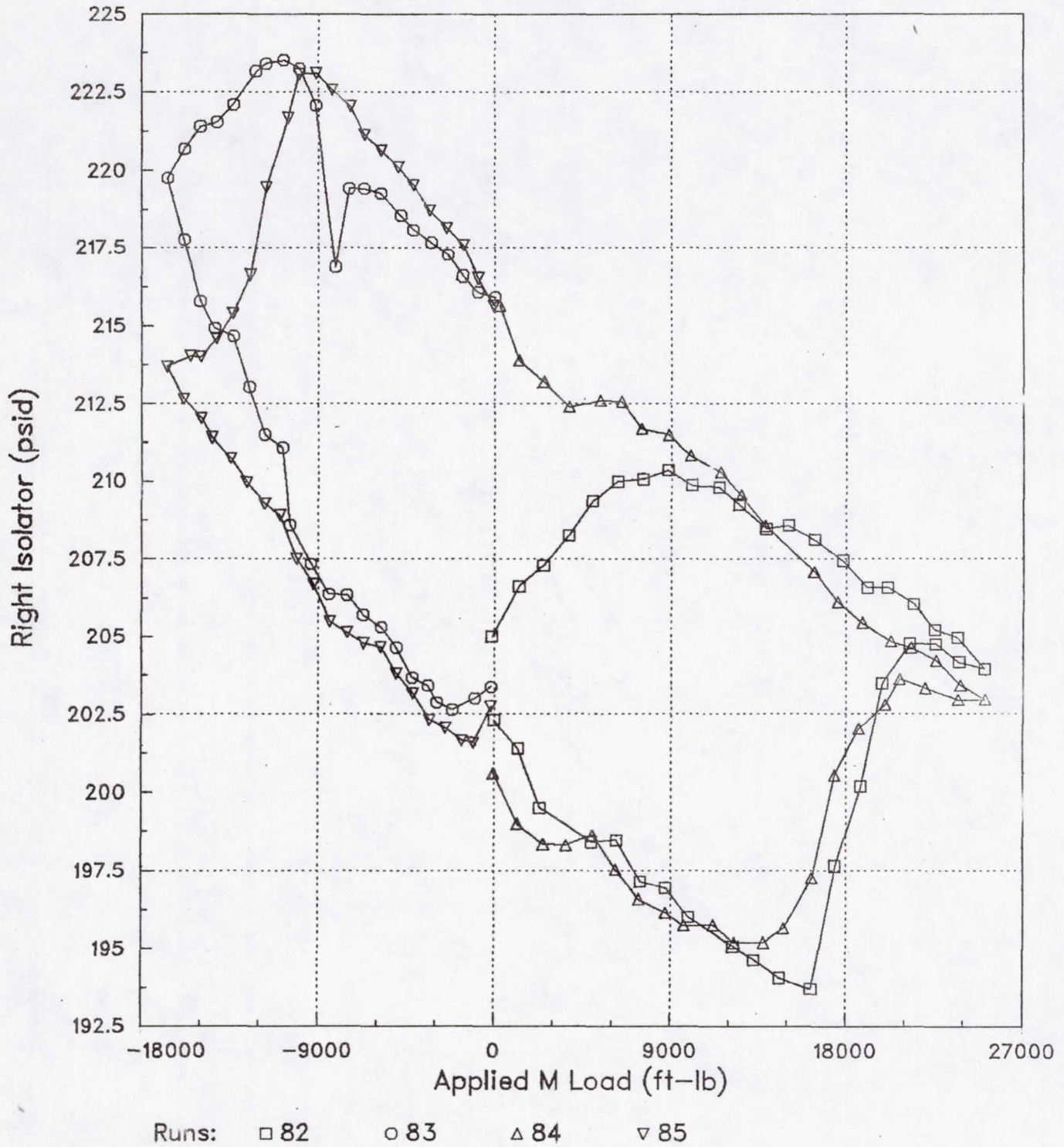
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



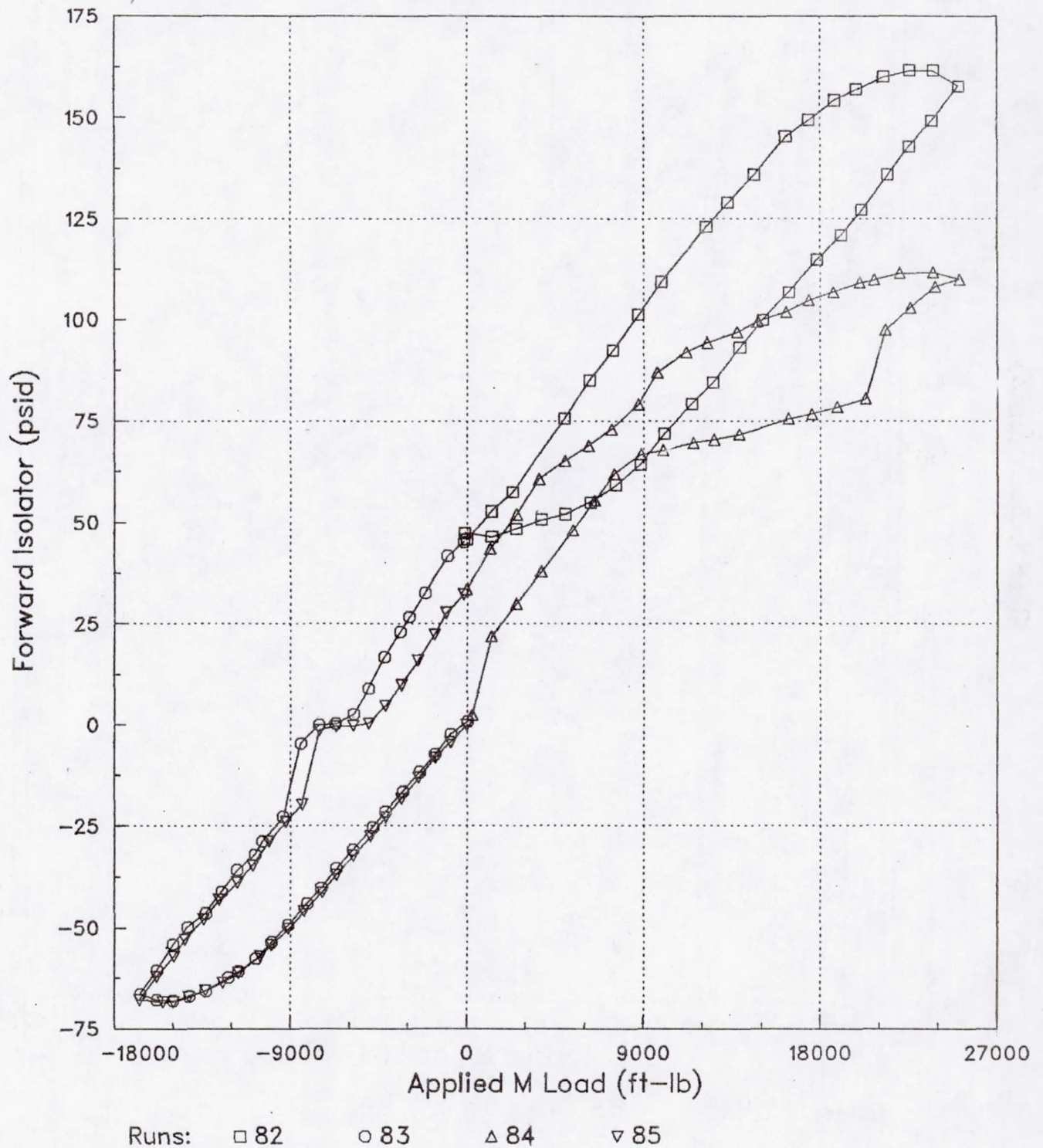
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



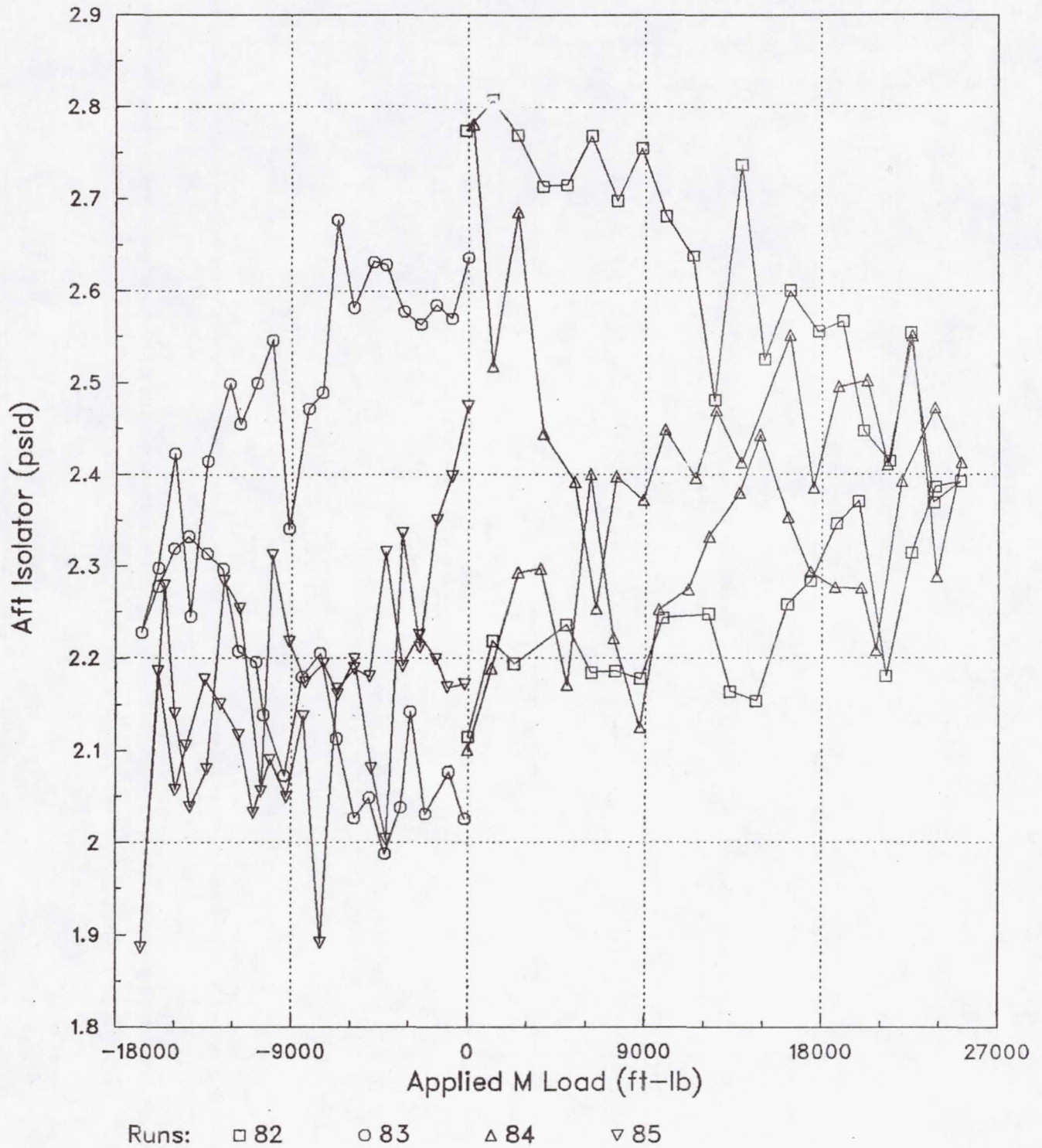
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



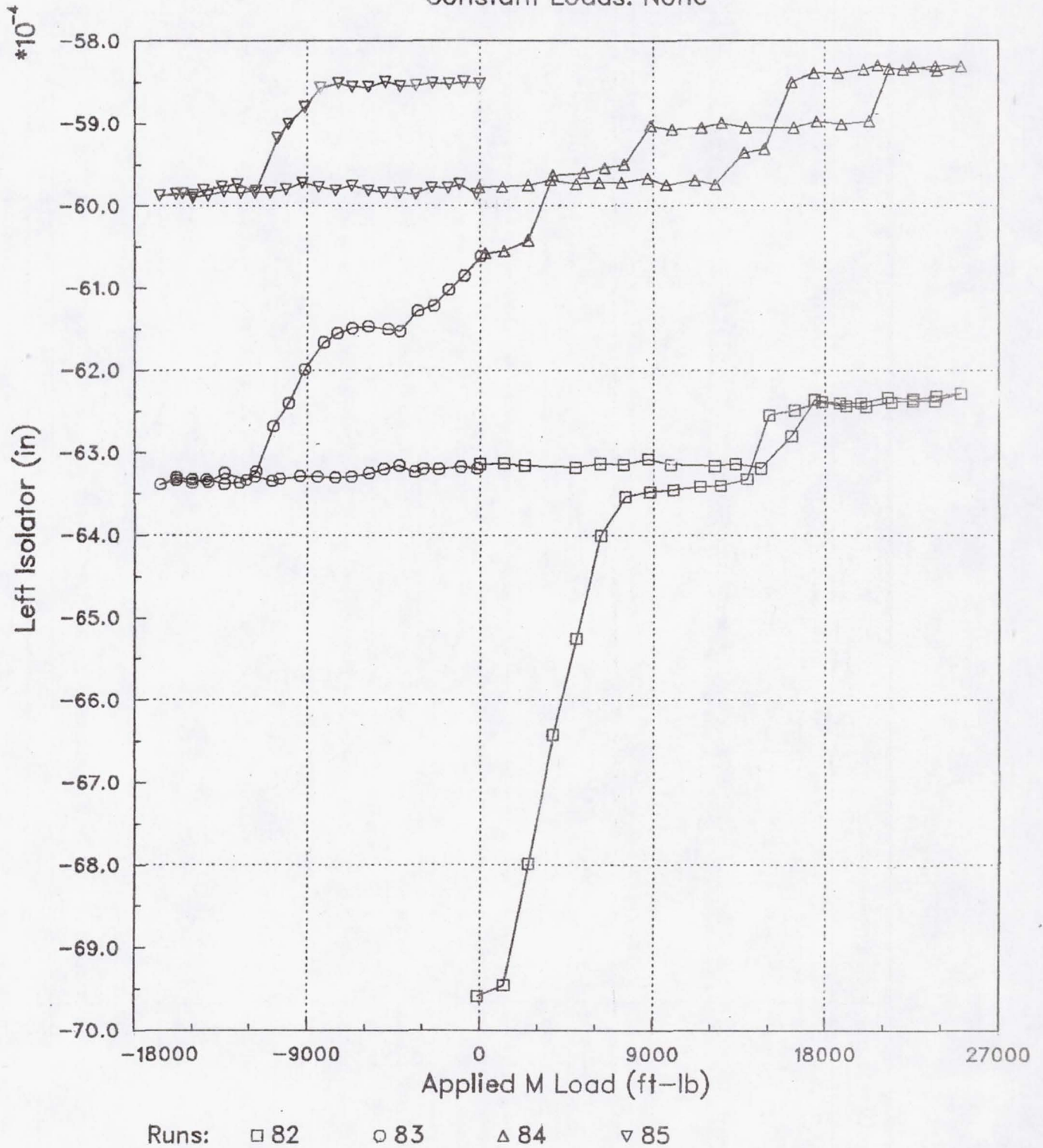
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



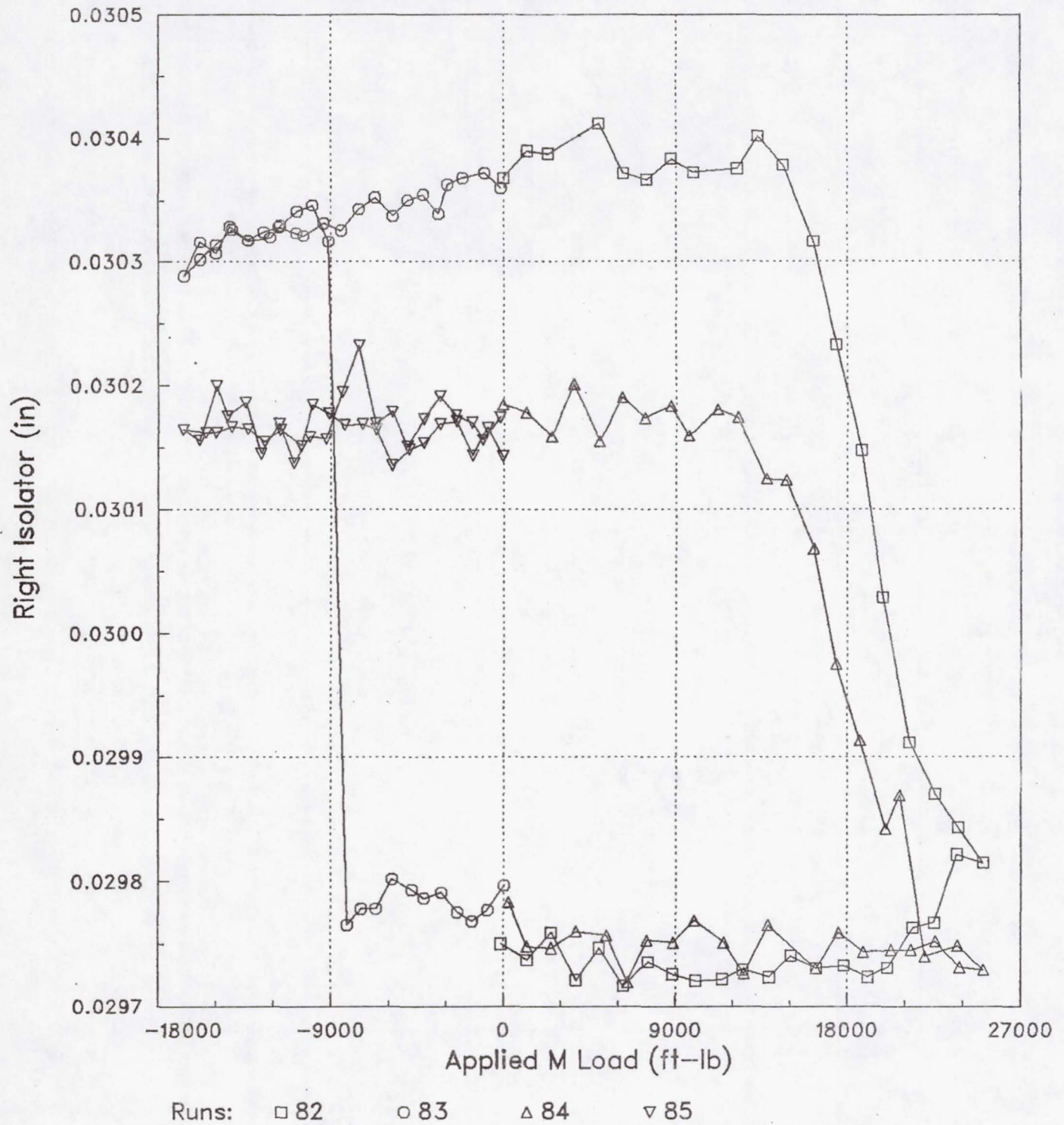
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



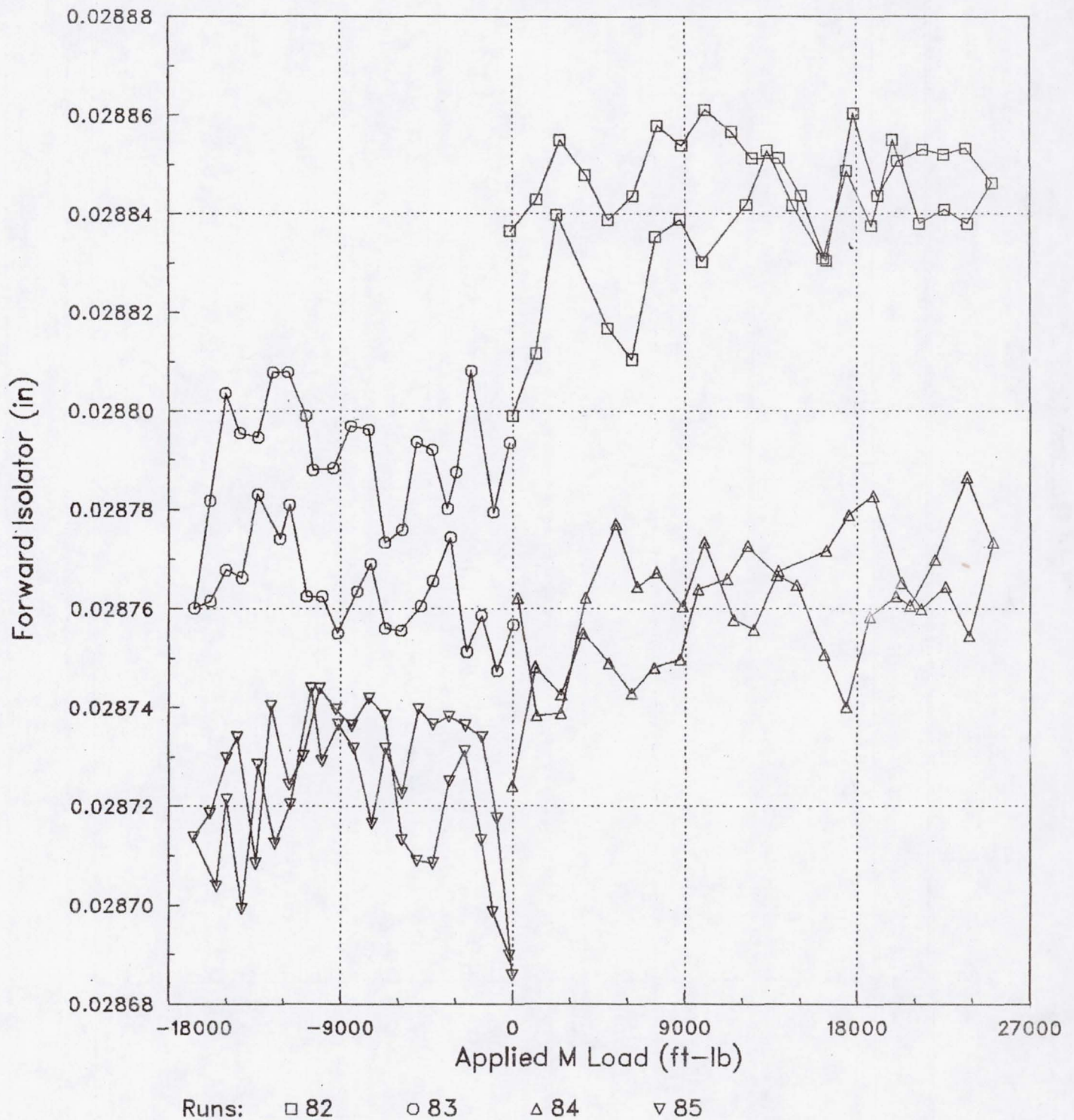
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



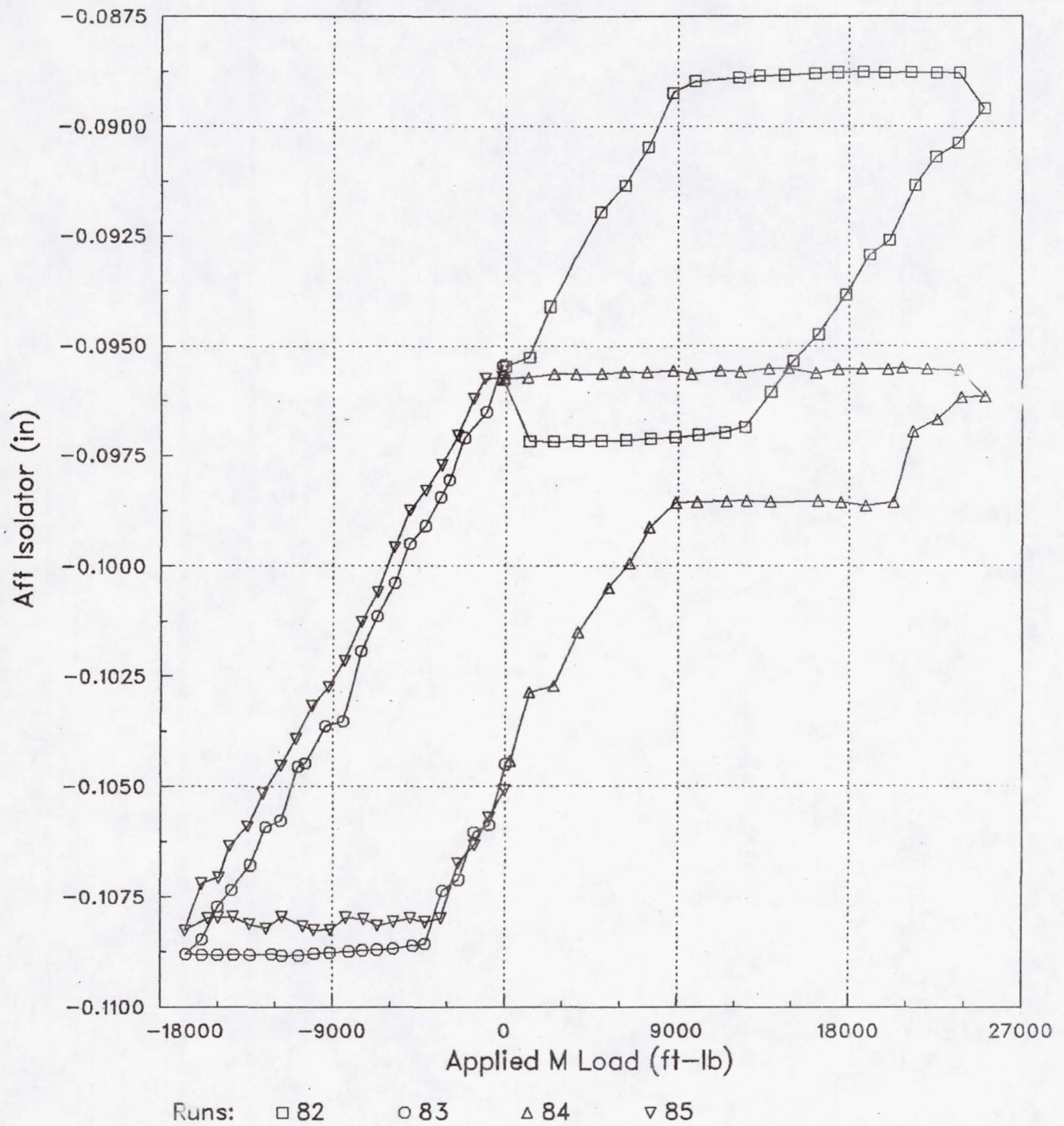
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



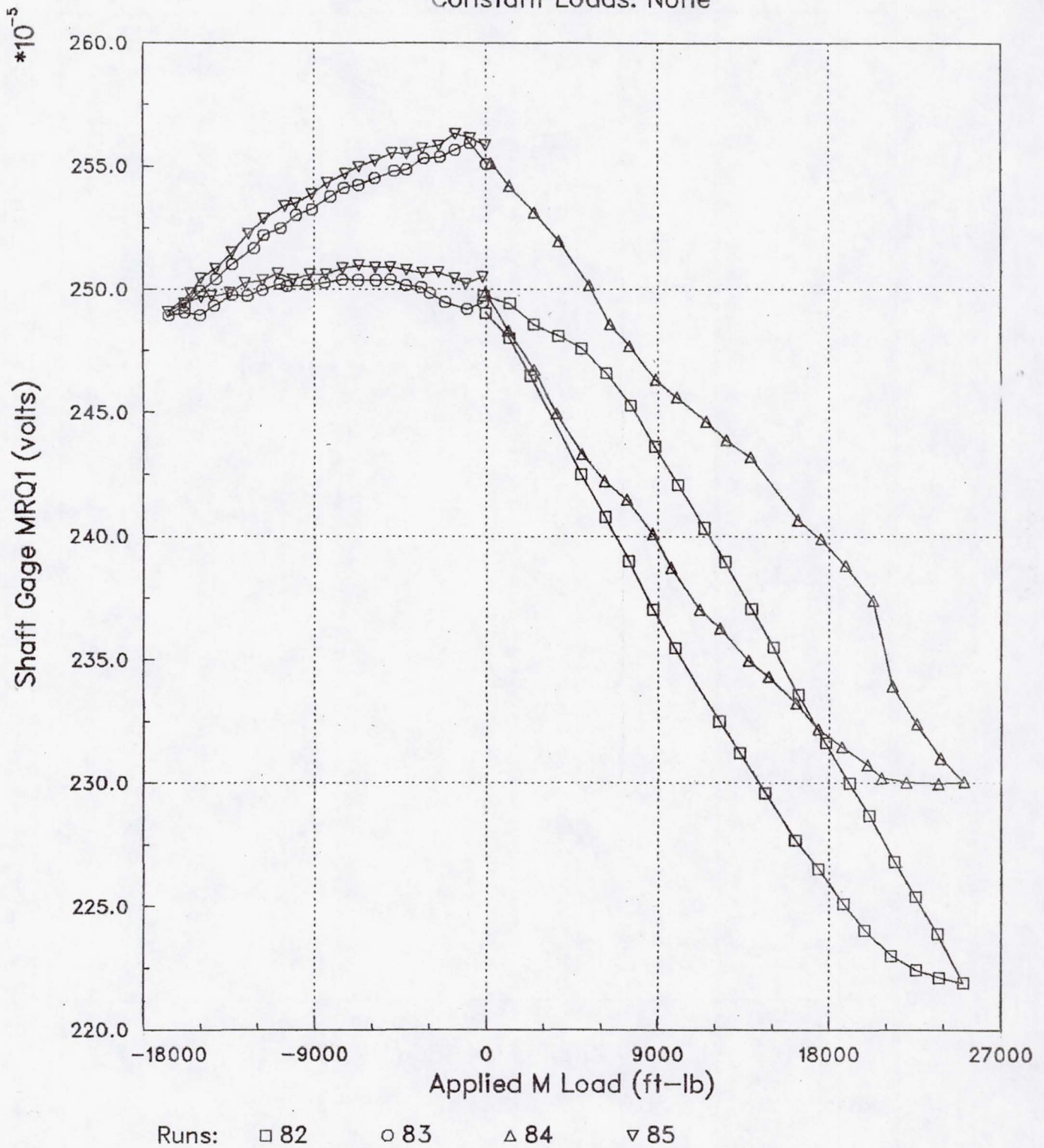
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



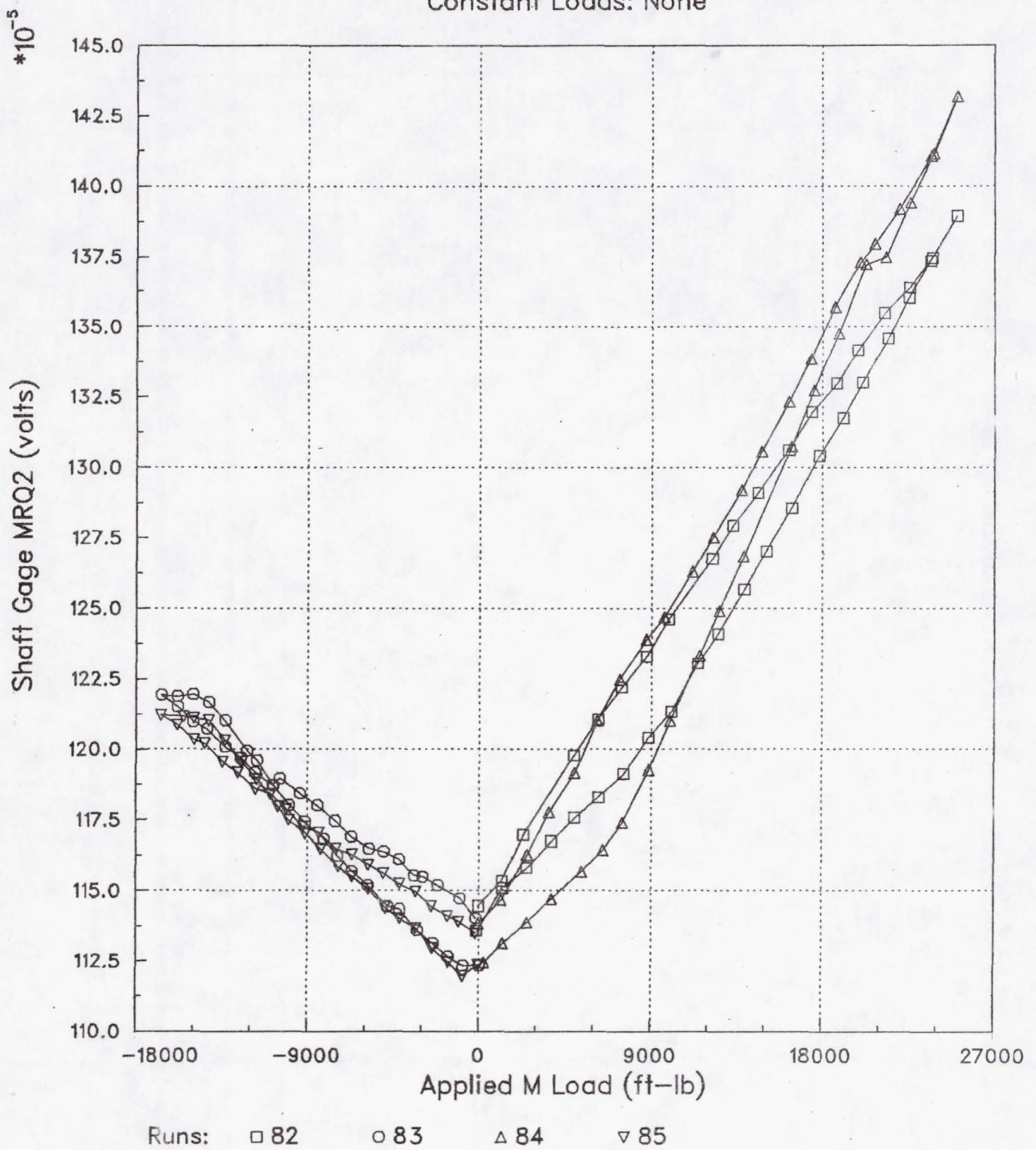
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



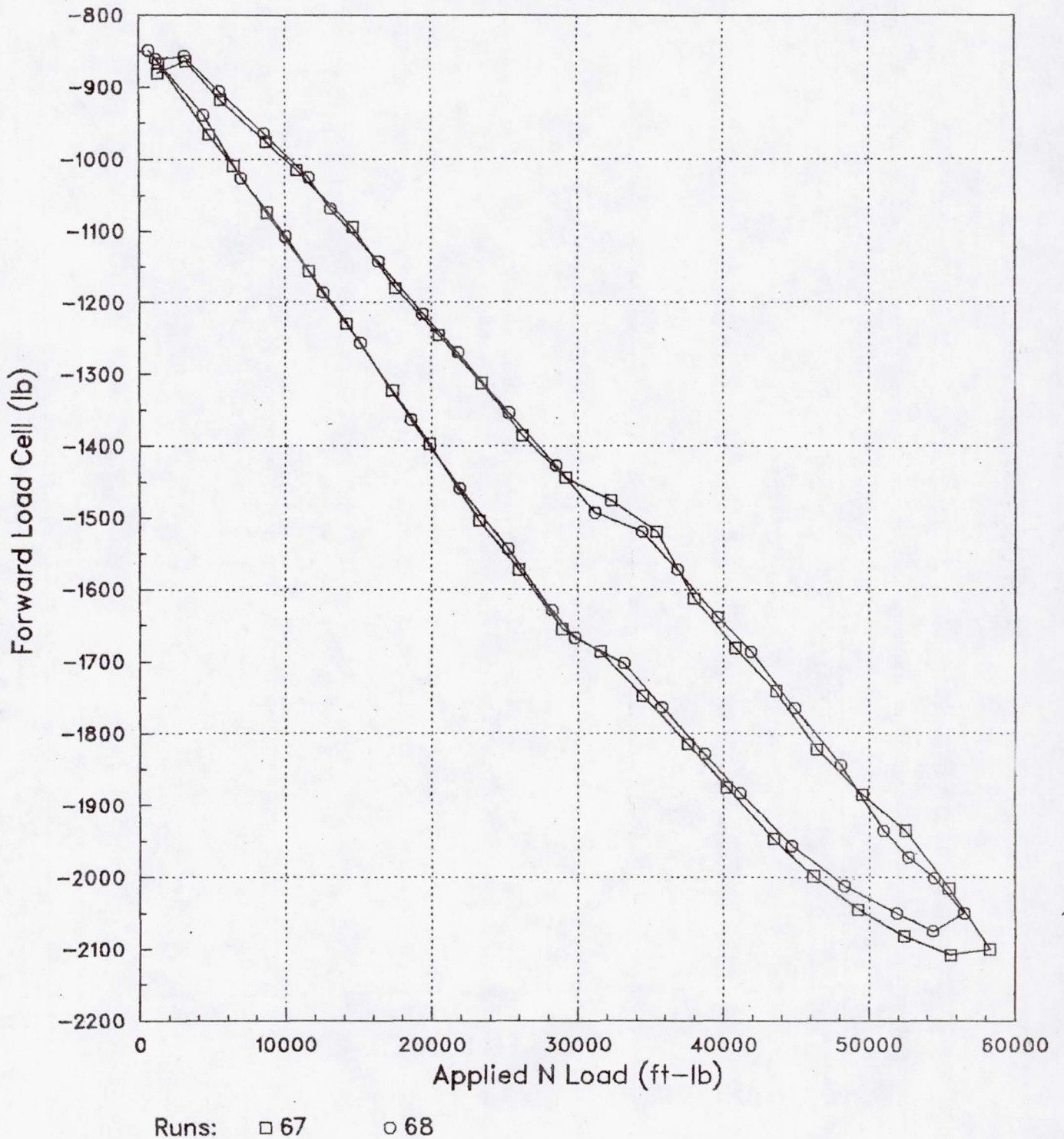
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: None



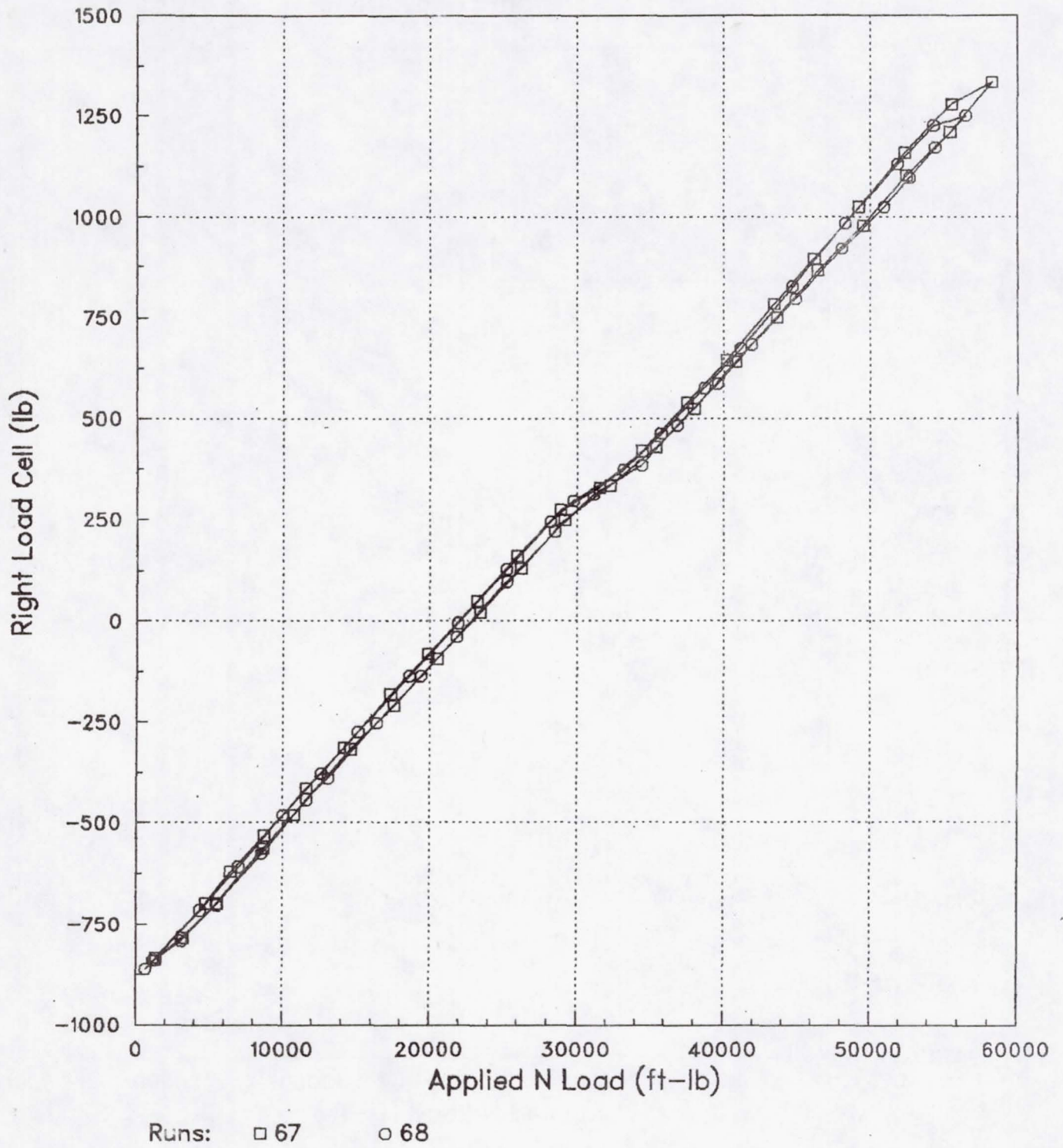
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



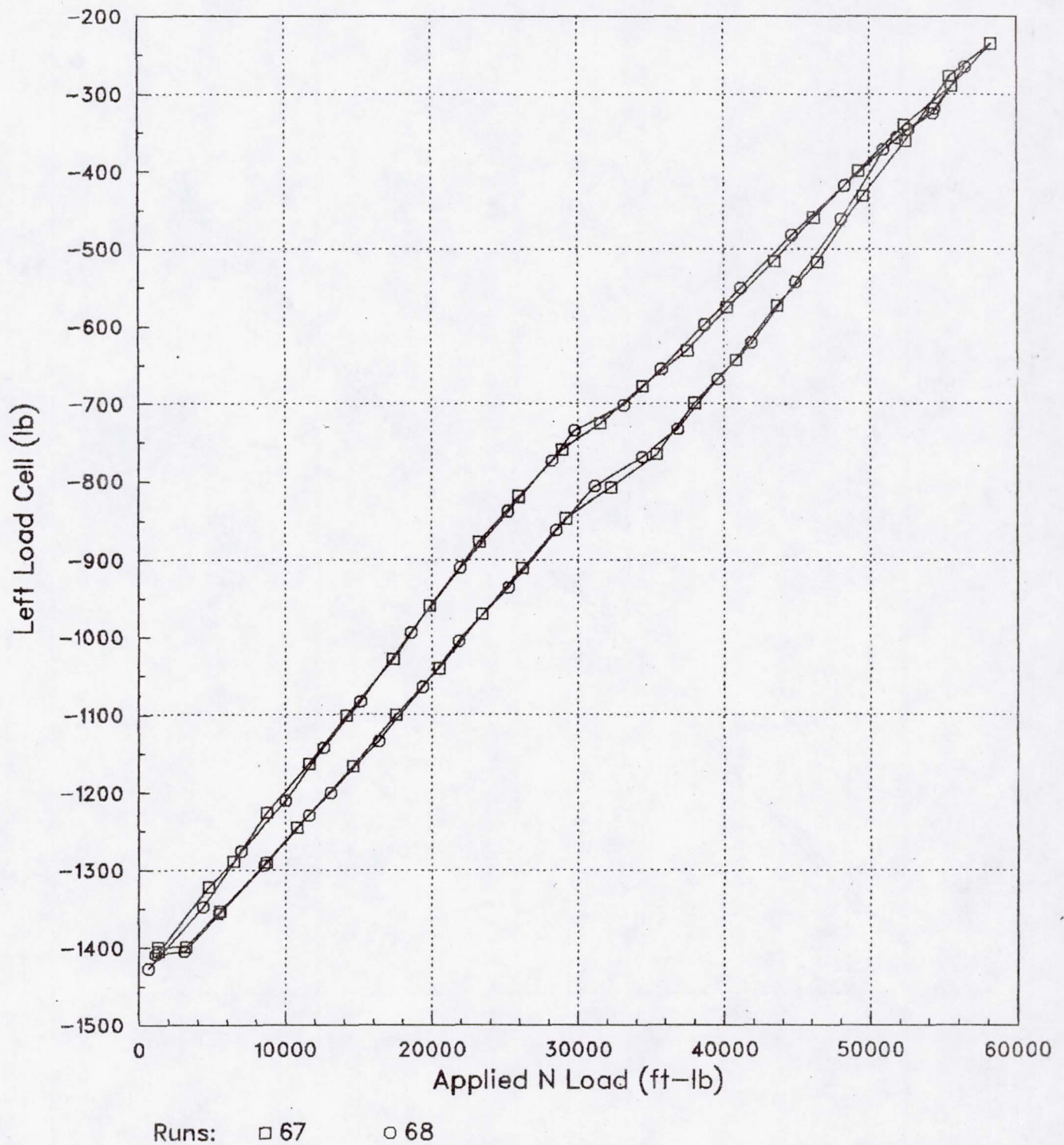
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



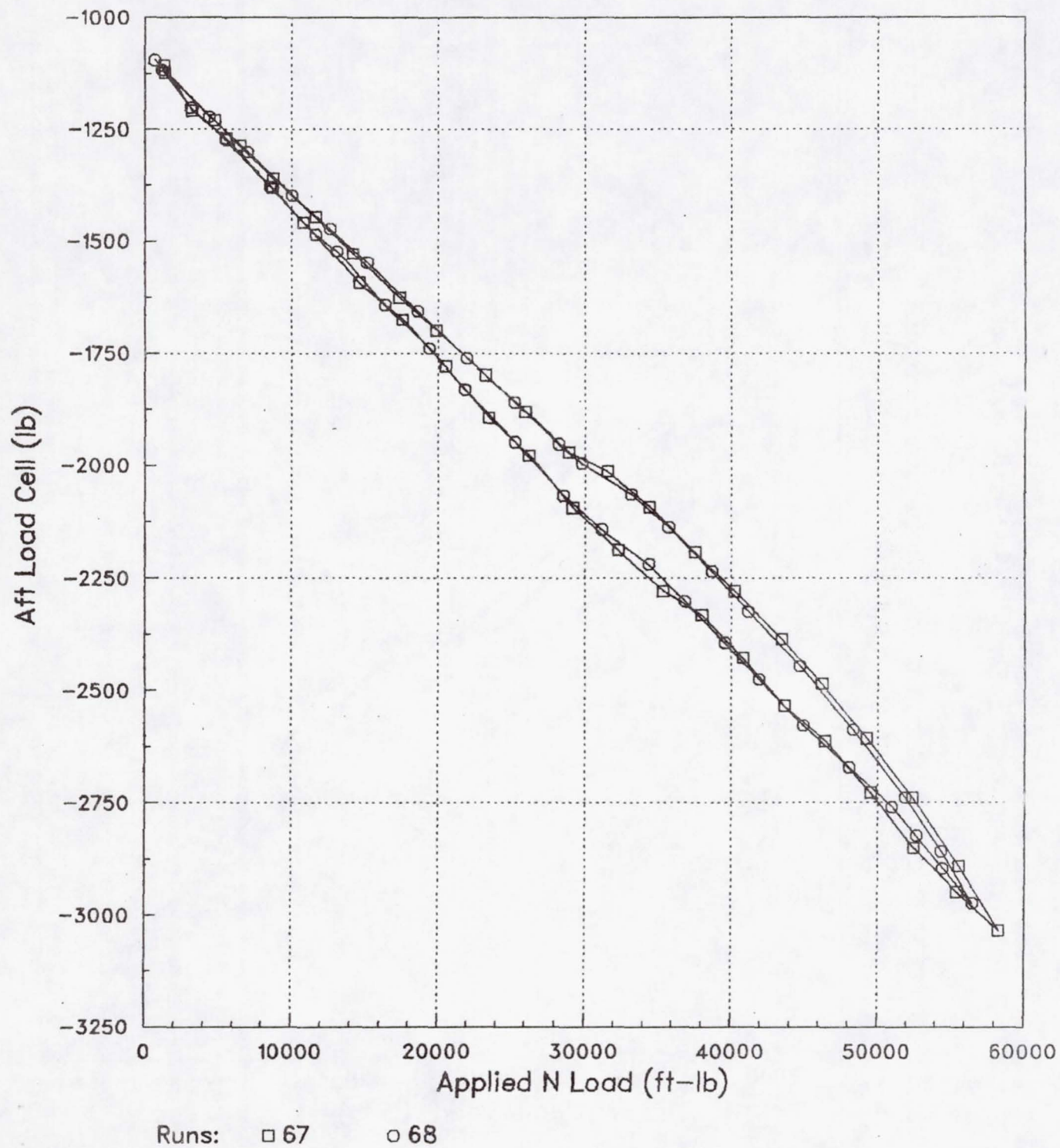
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



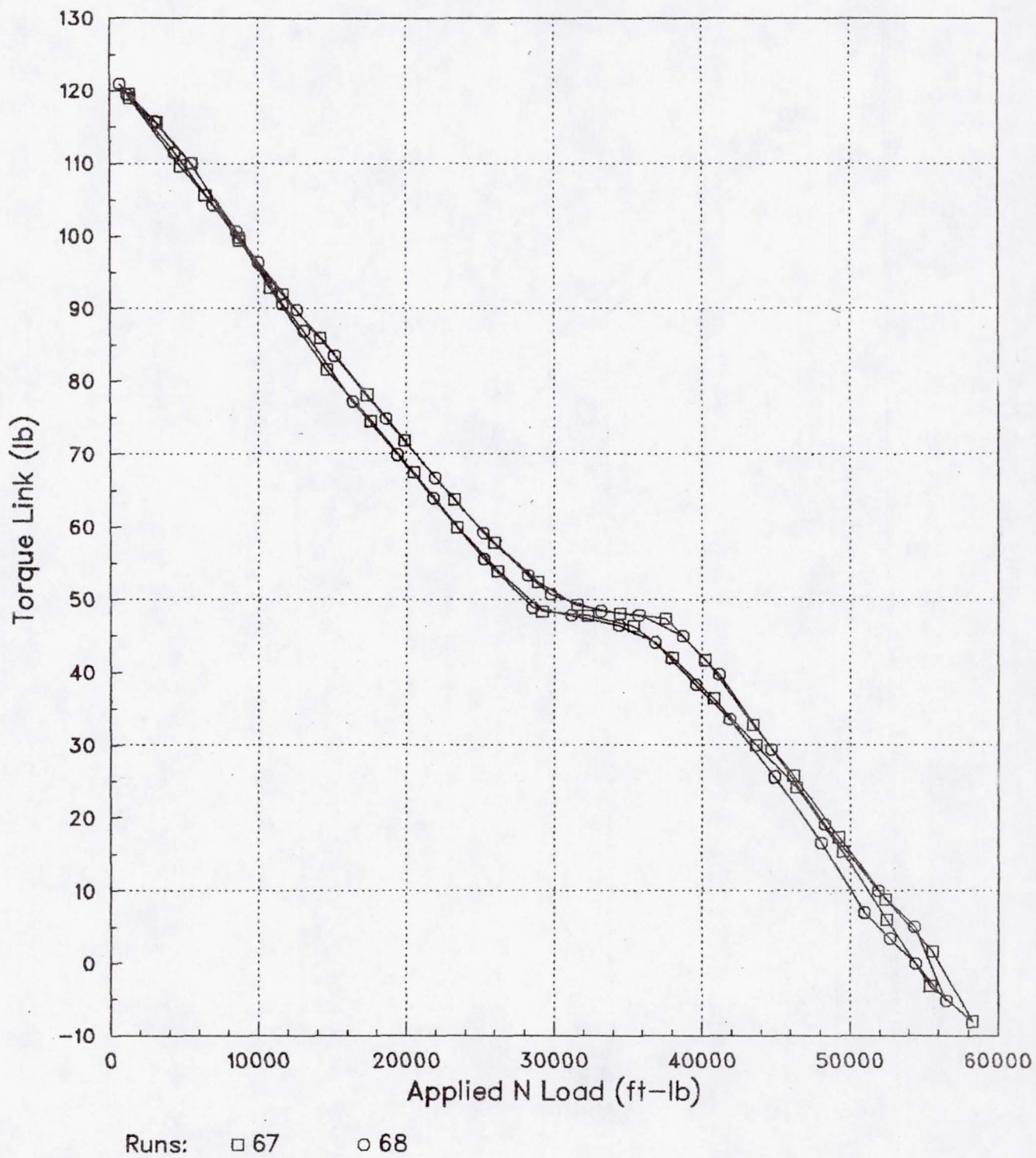
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



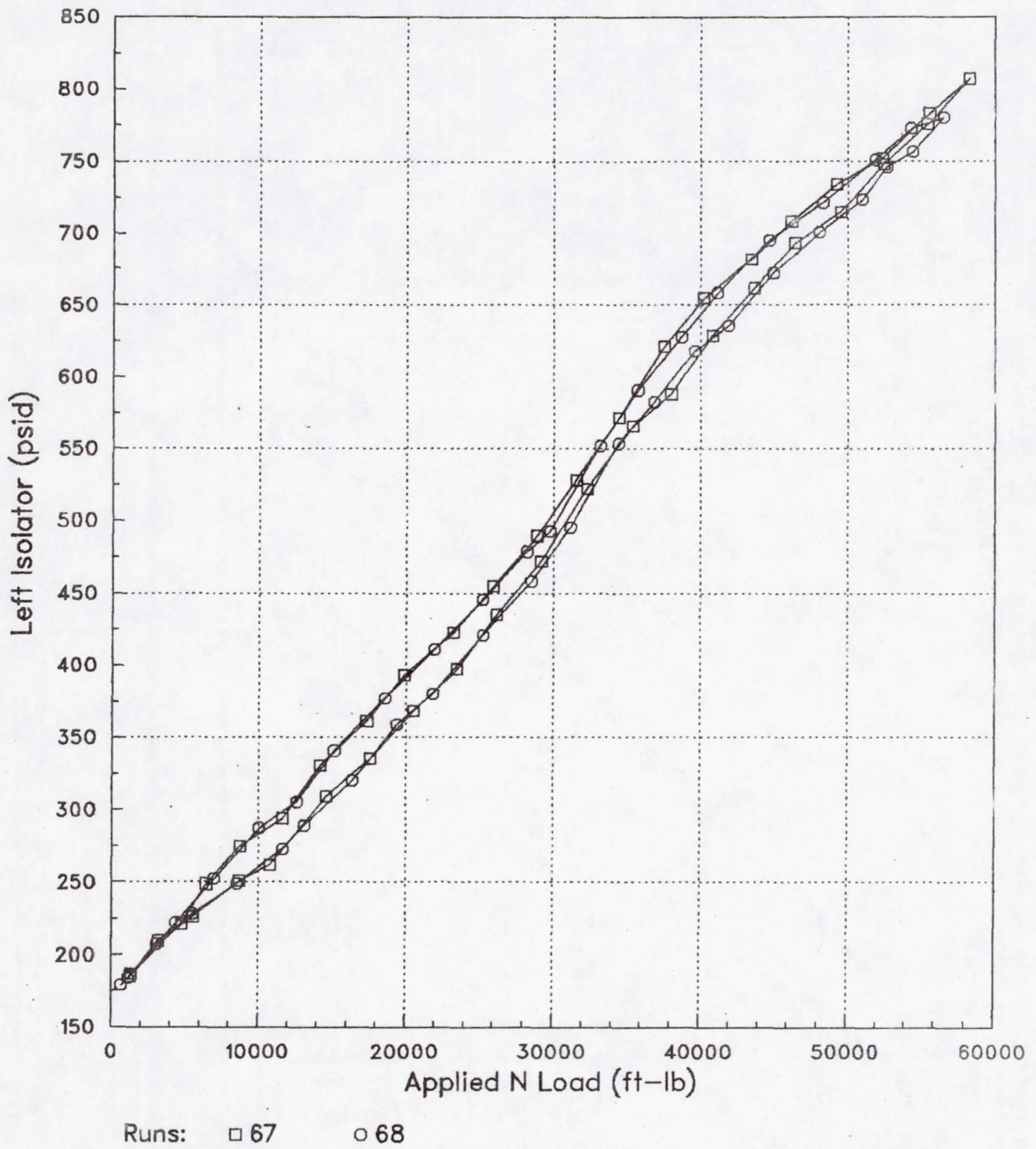
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



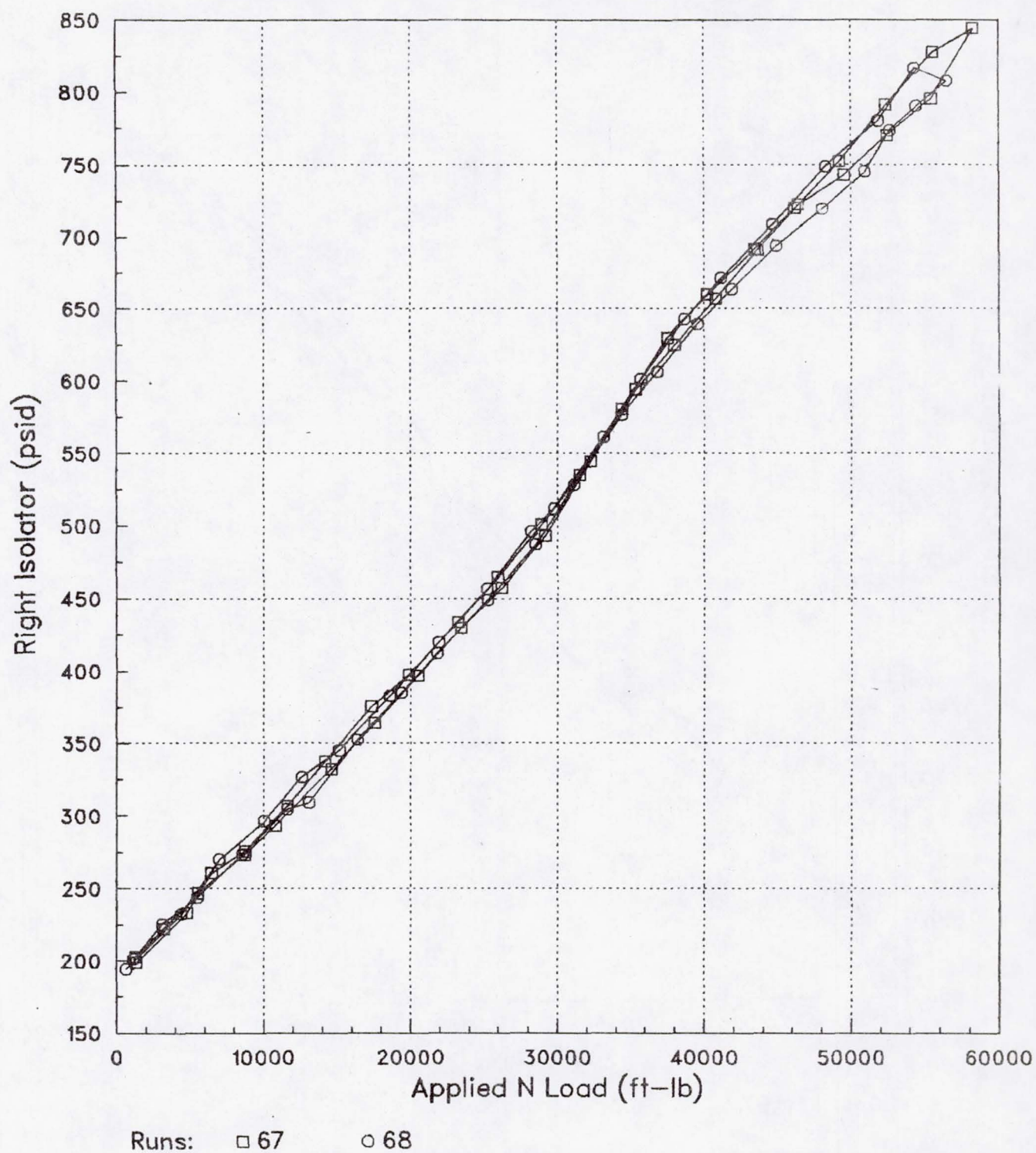
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



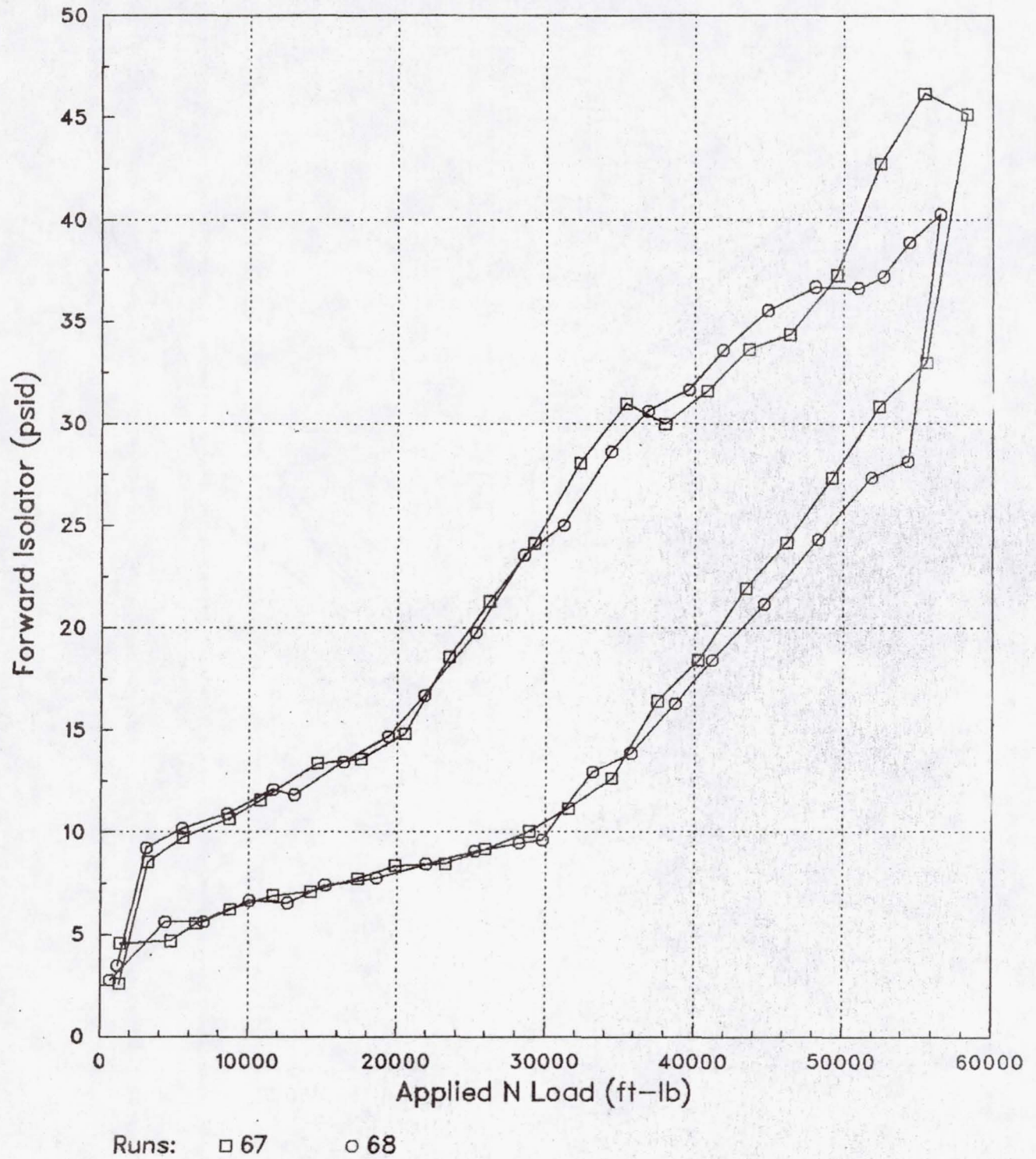
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



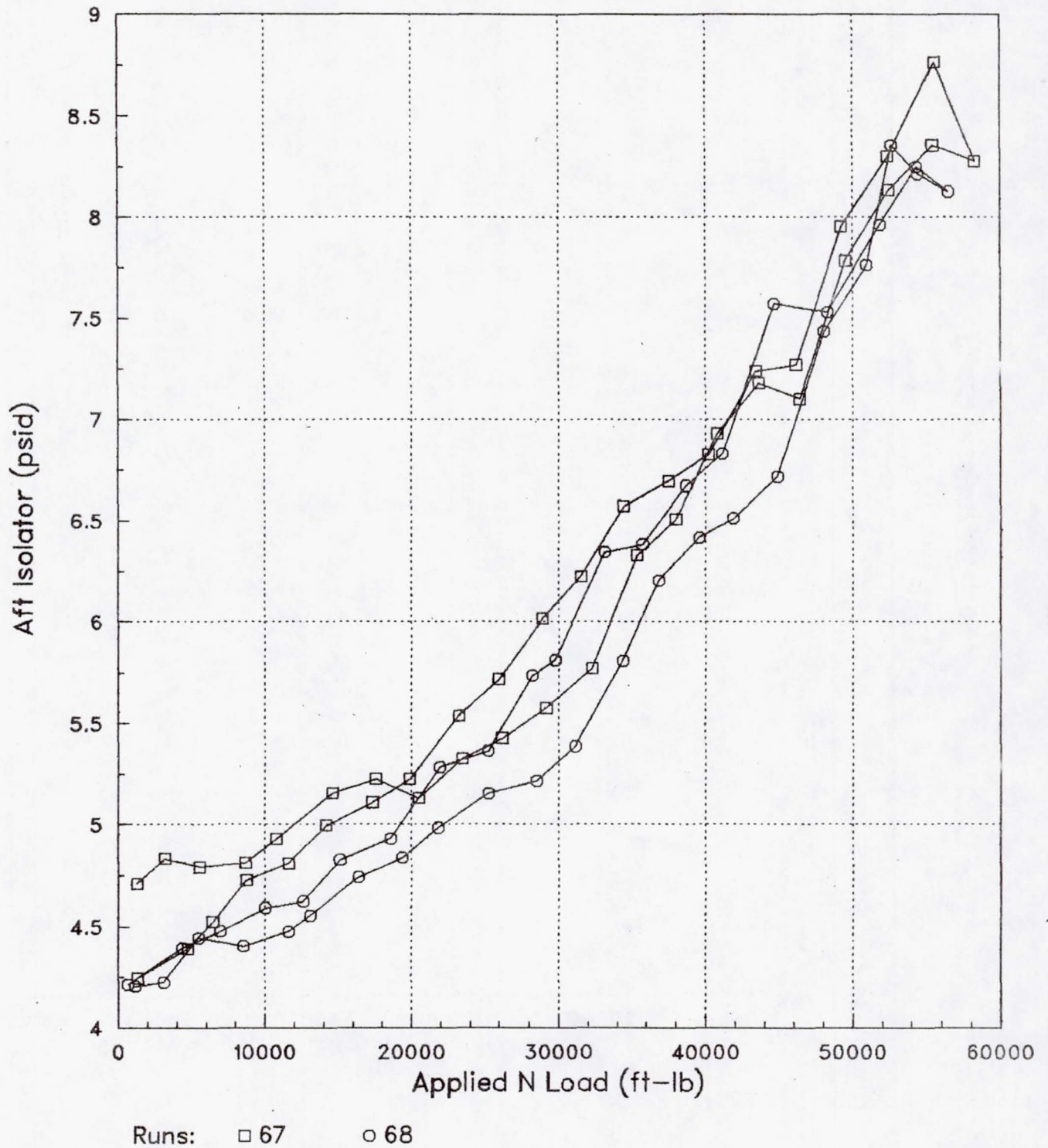
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



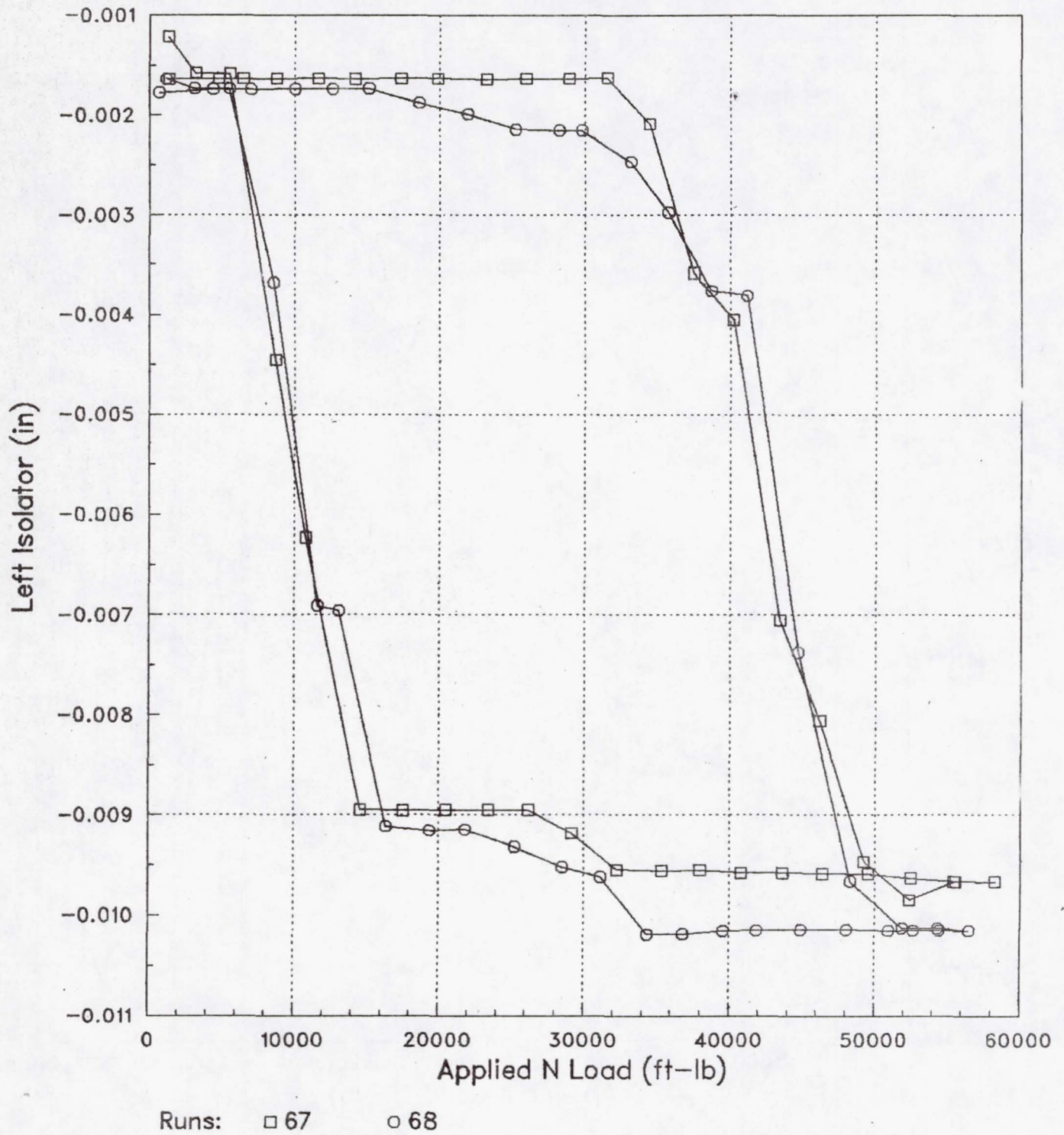
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



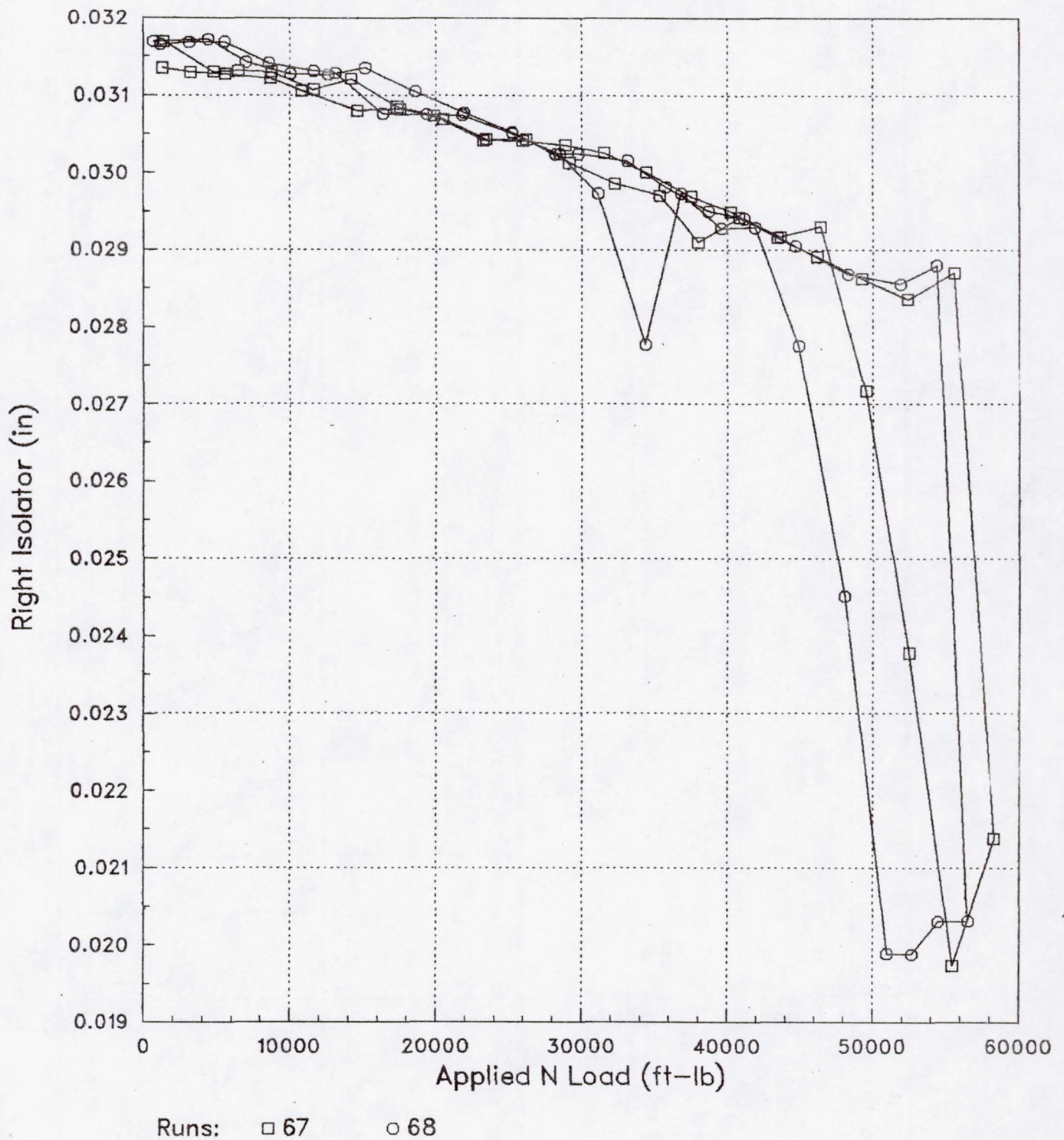
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



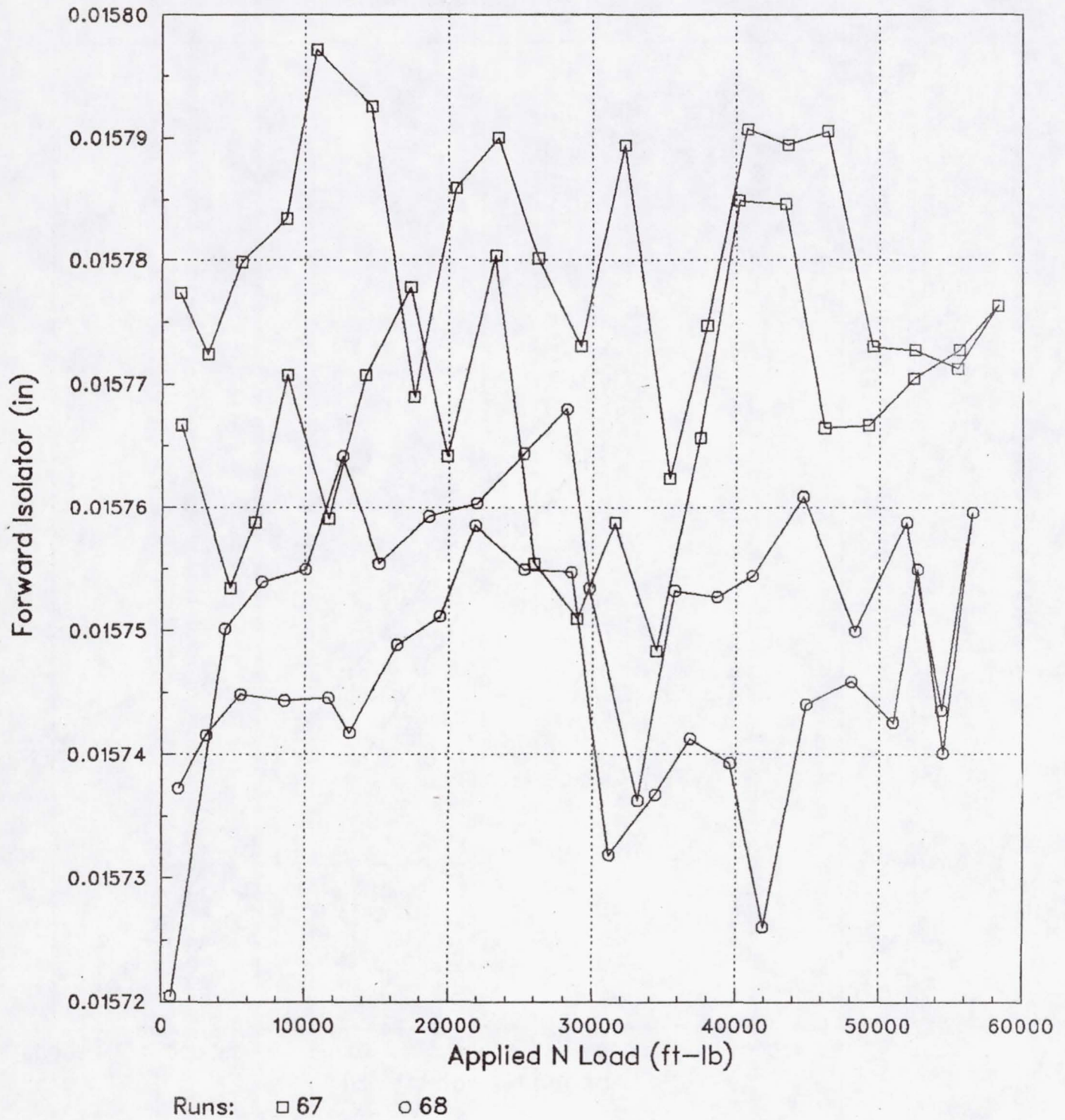
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



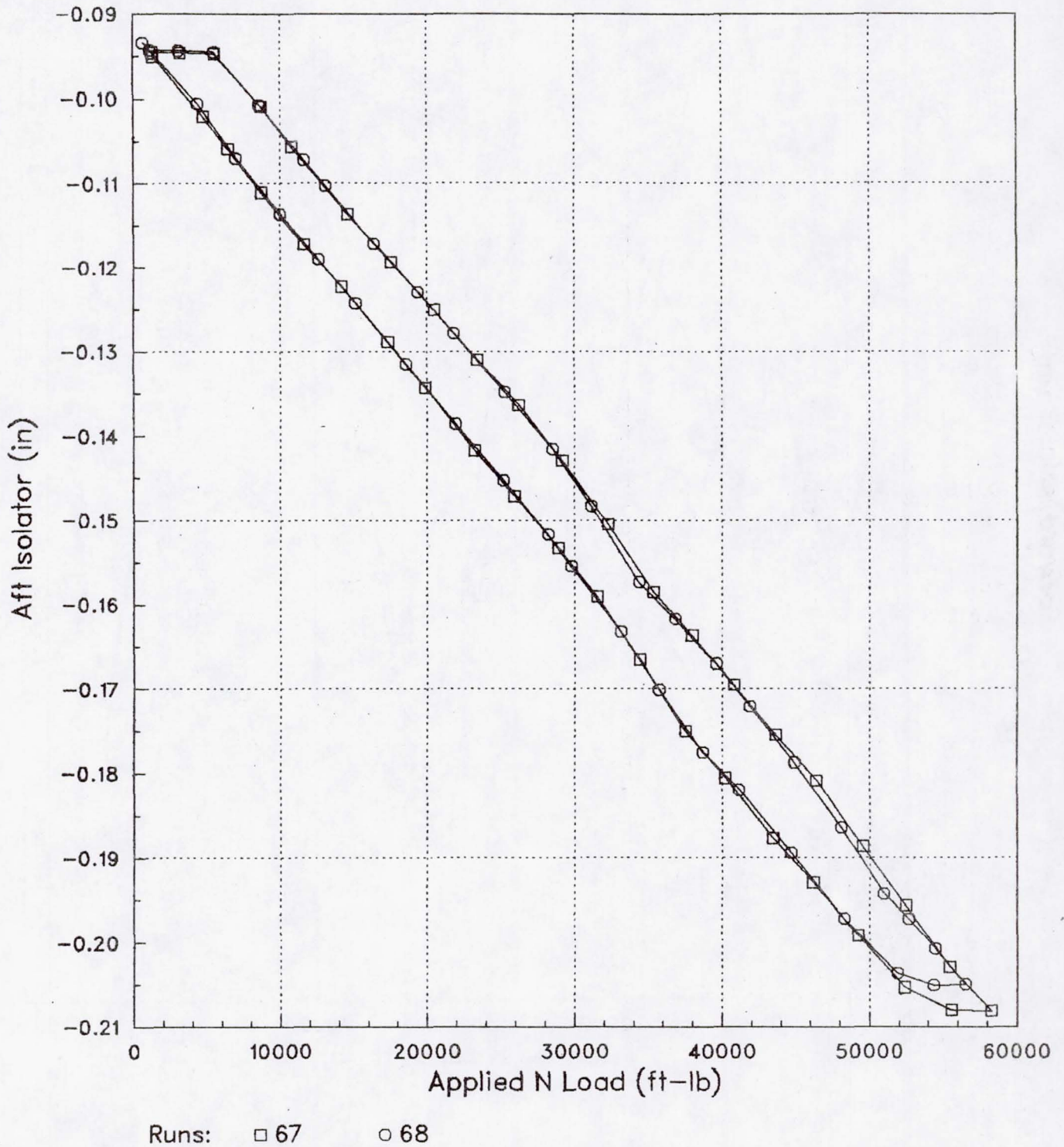
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



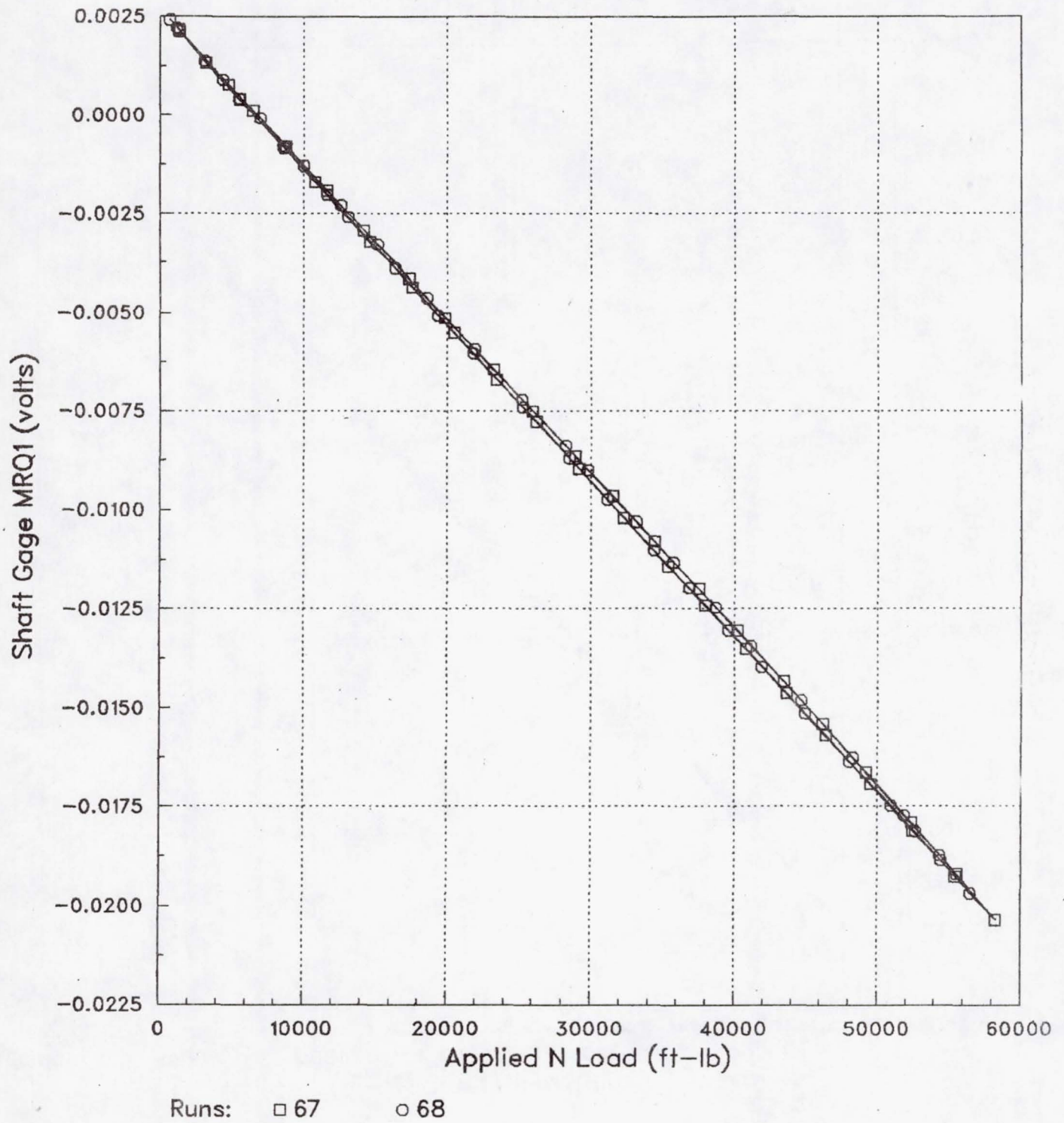
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



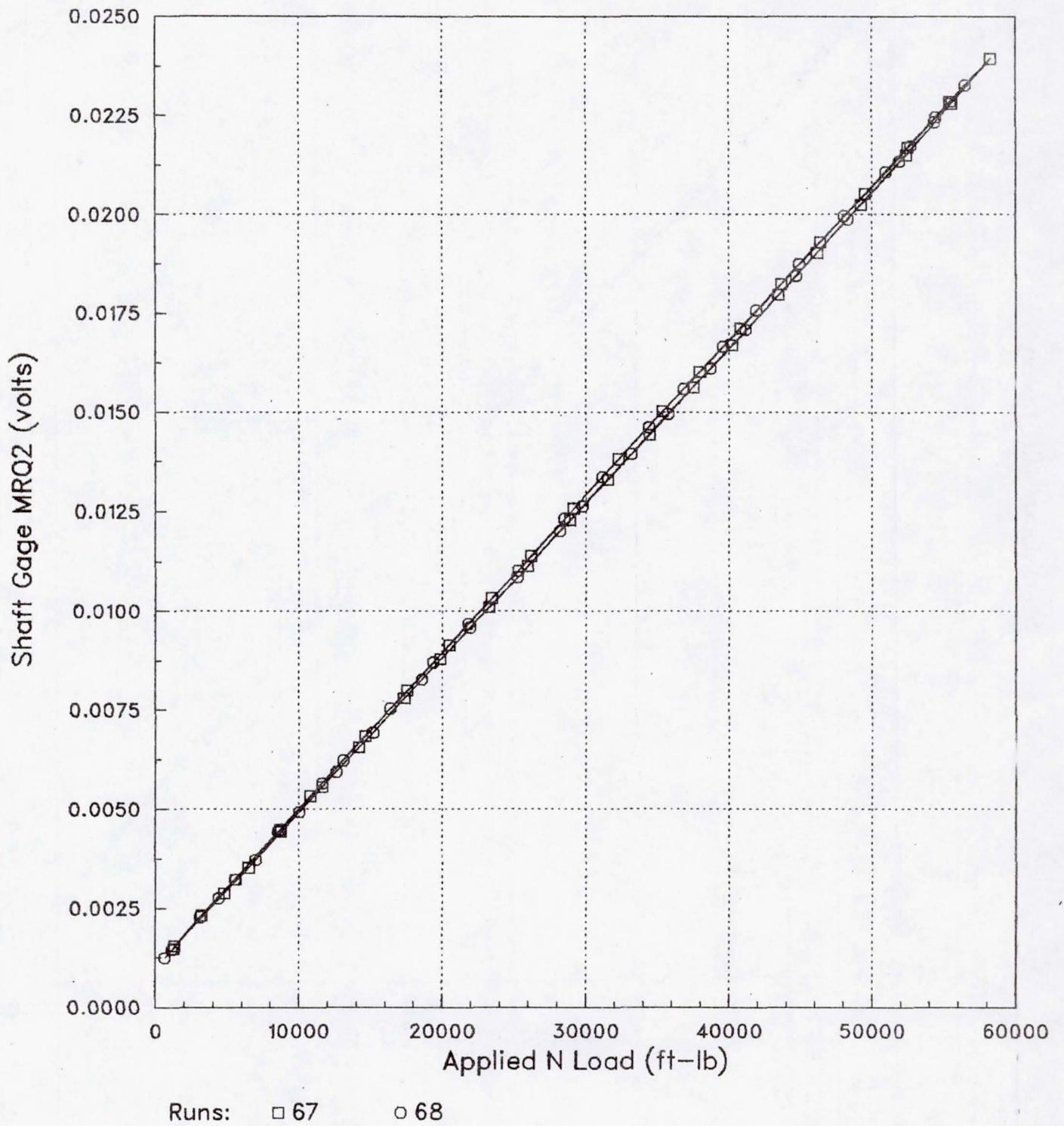
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Loads: None



RSRA 741 1983 ROTOR CALIBRATION

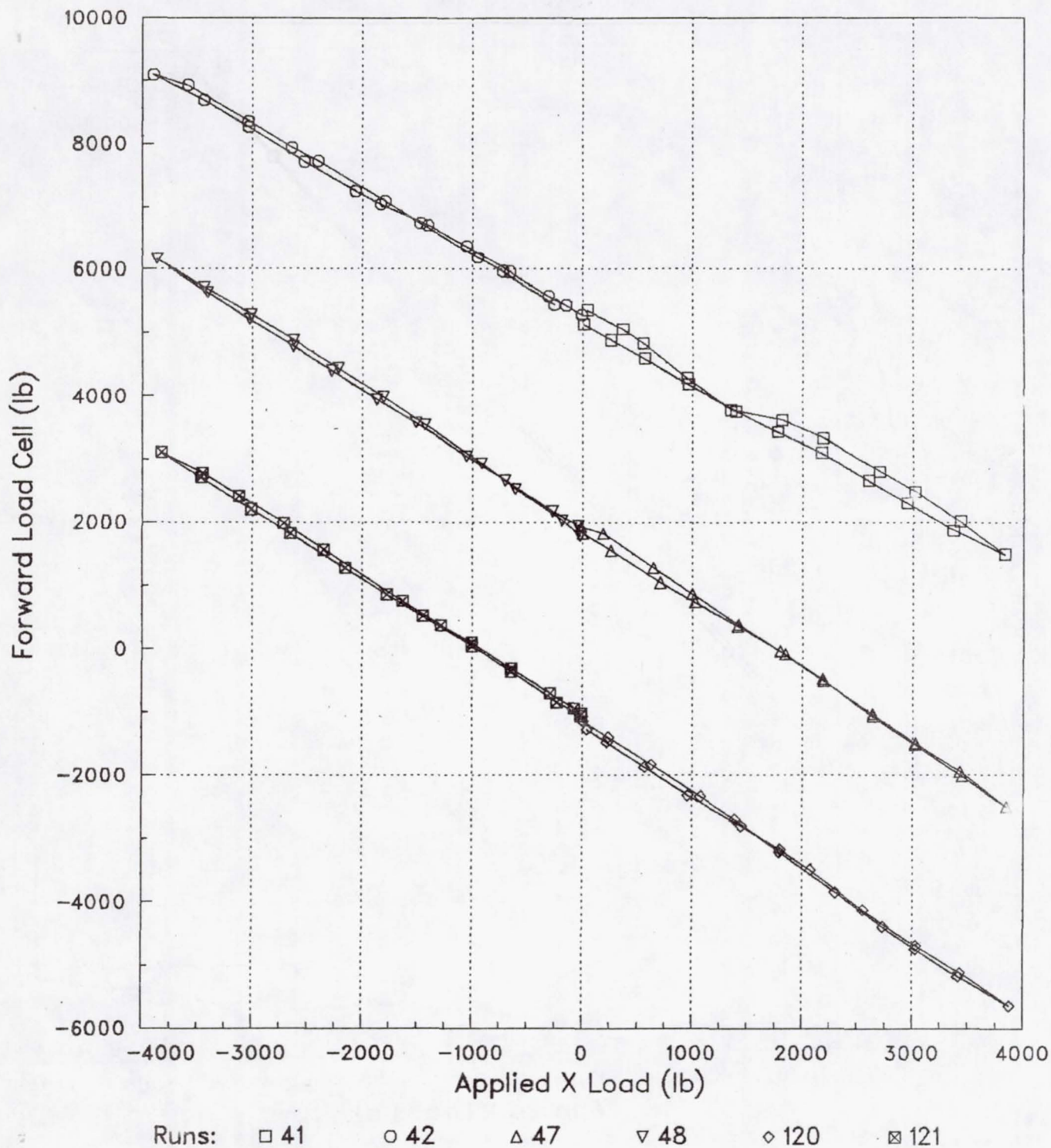
Applied N Load
Constant Loads: None



RSRA 741 1983 ROTOR CALIBRATION

Applied X Load

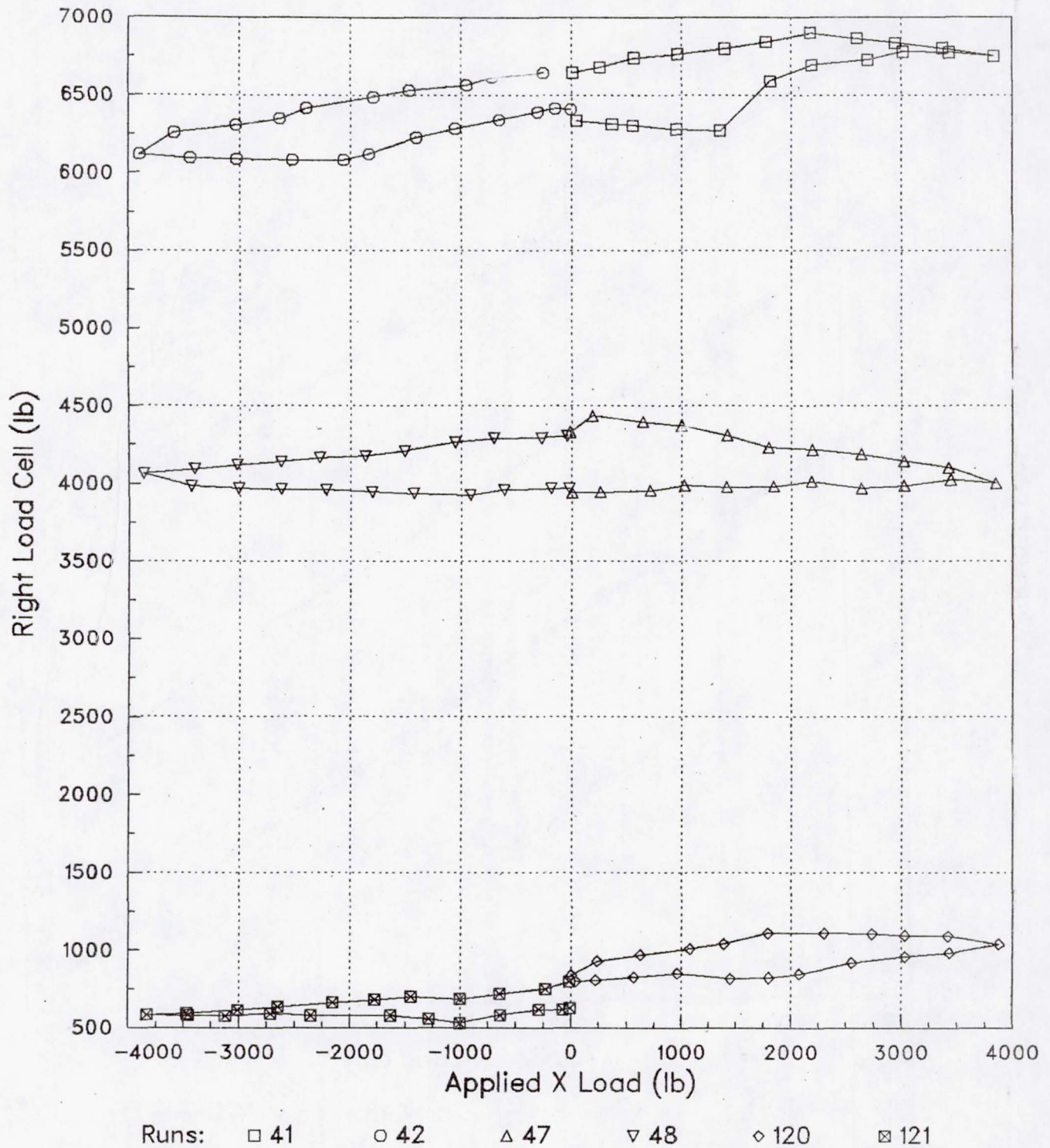
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied X Load

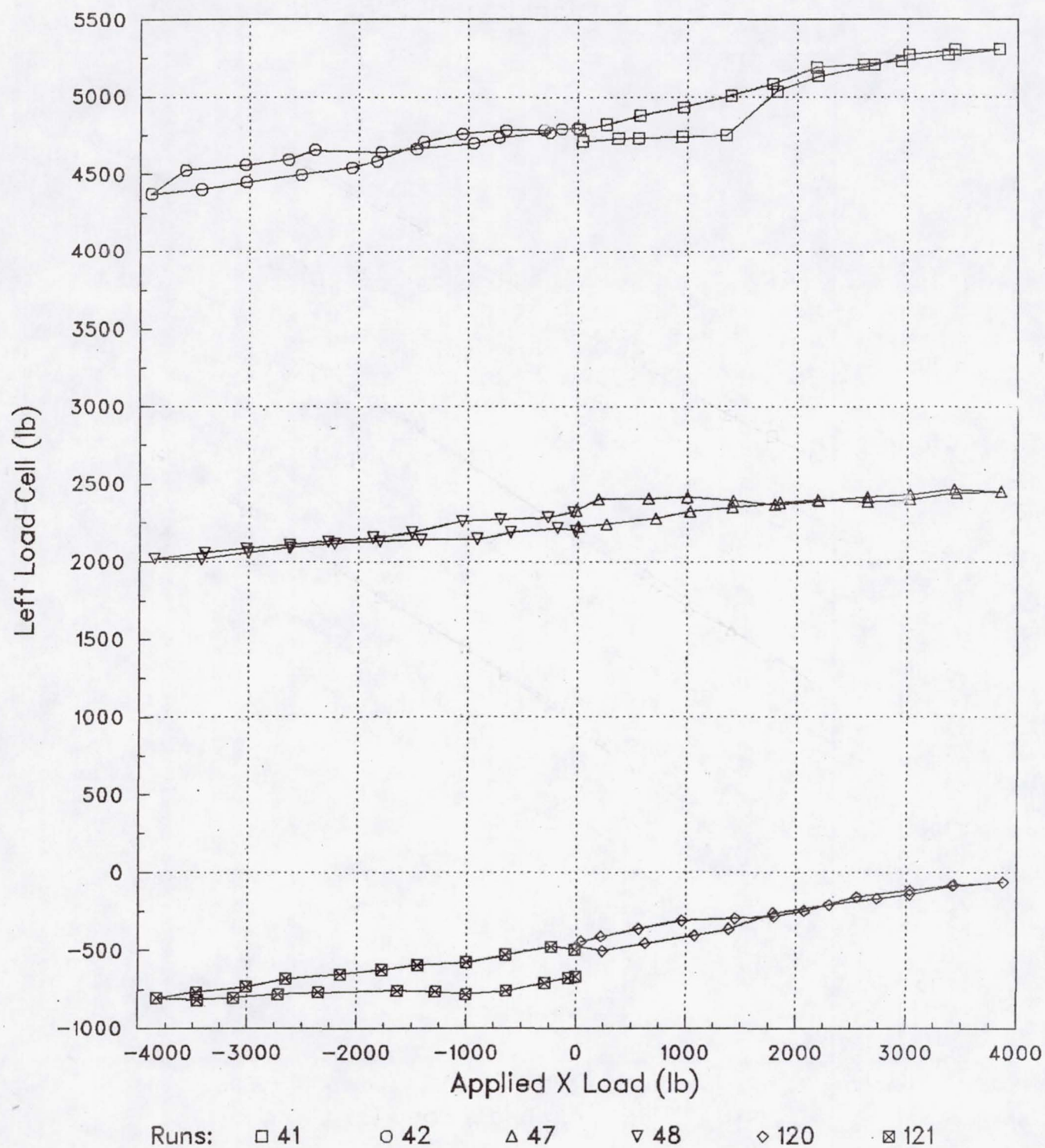
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

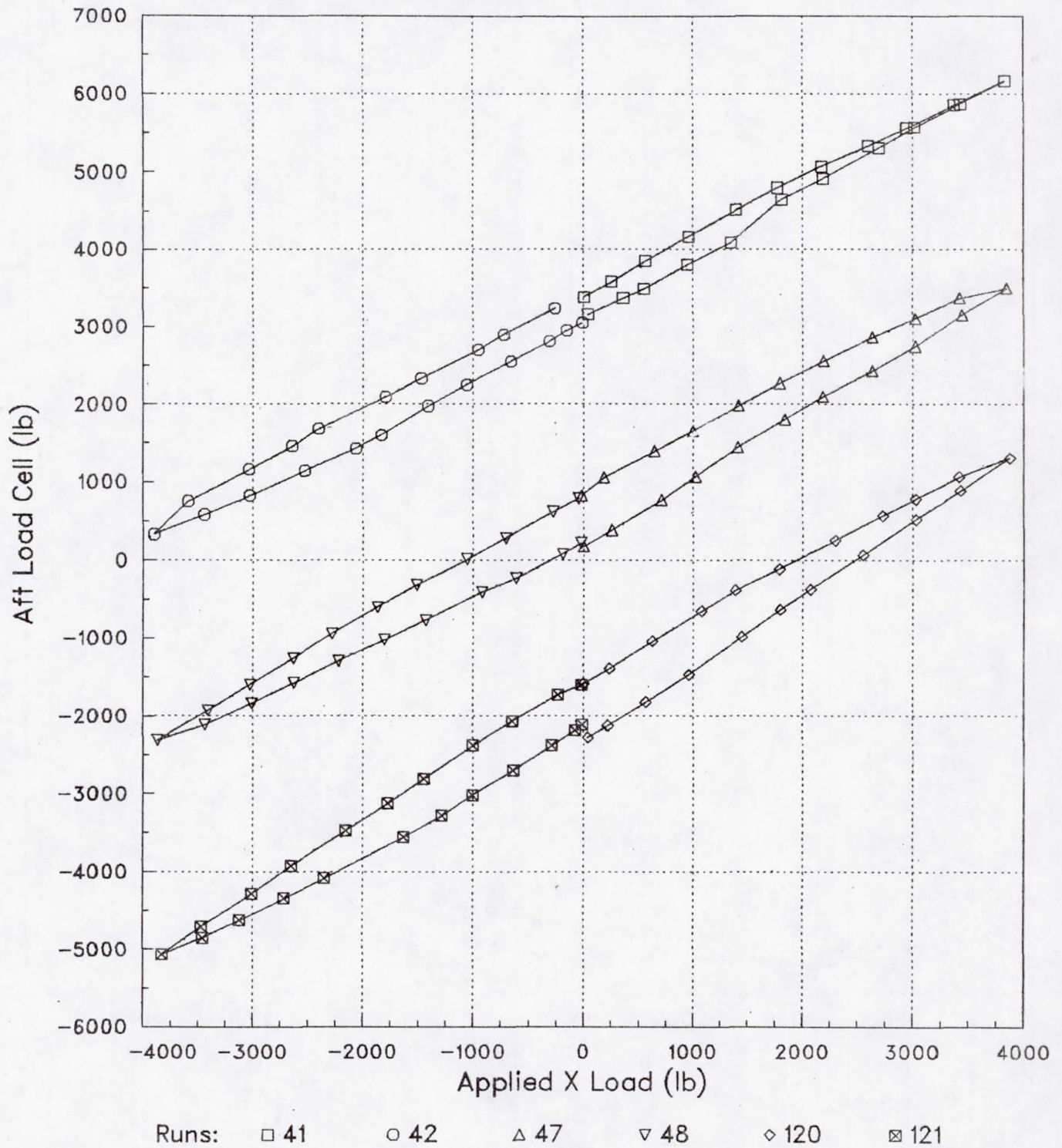
Applied X Load

Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

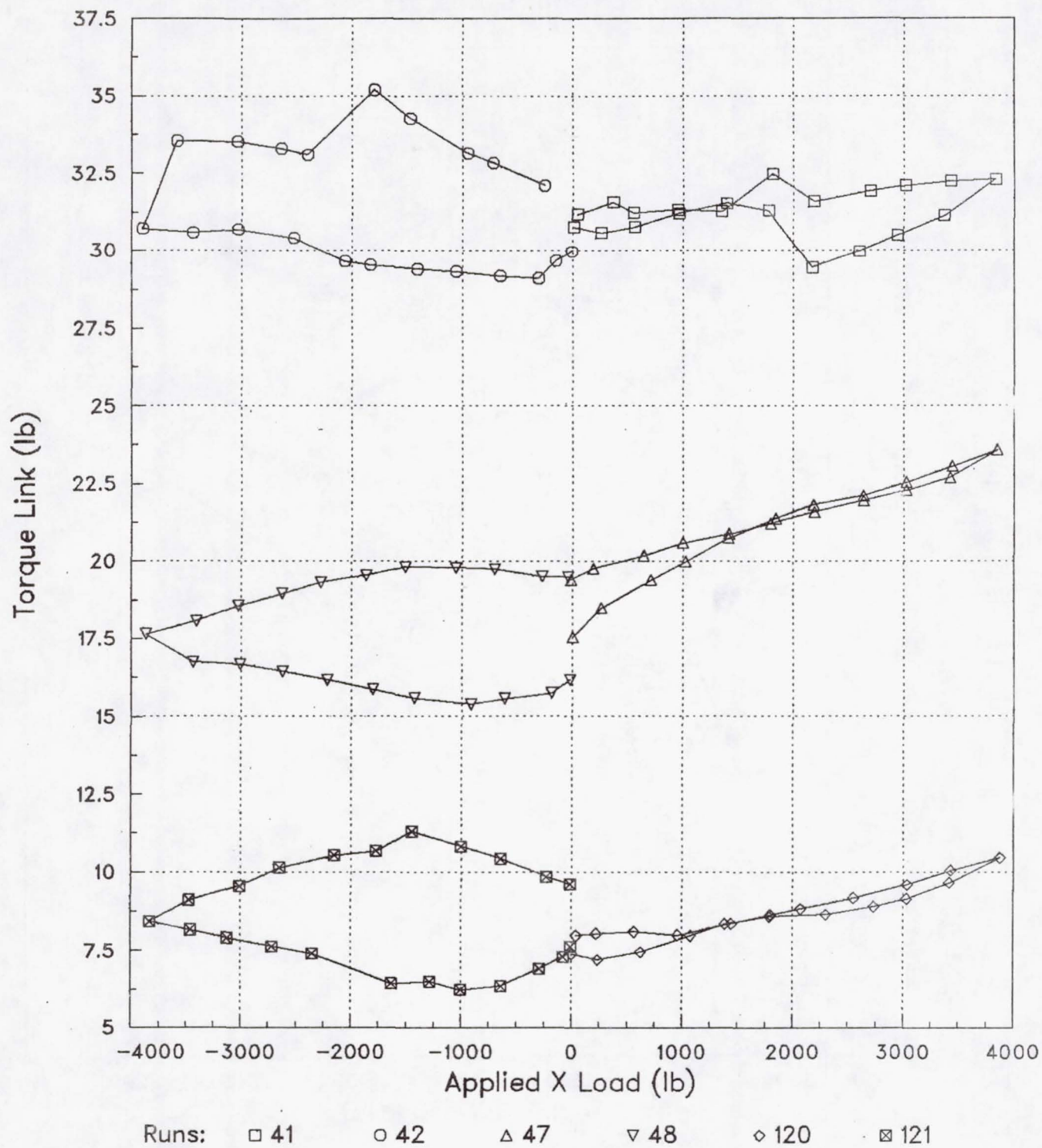
Applied X Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied X Load

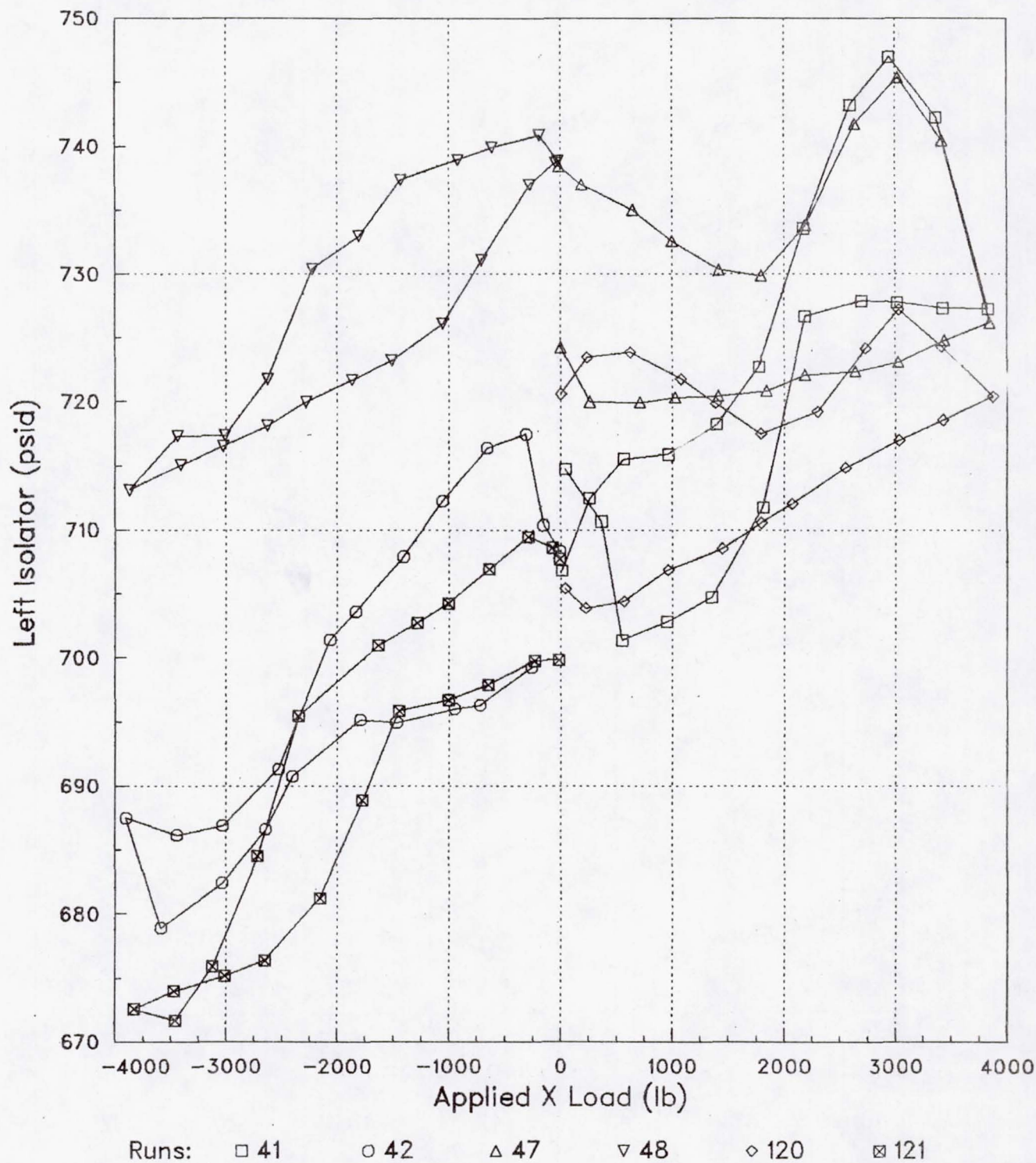
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

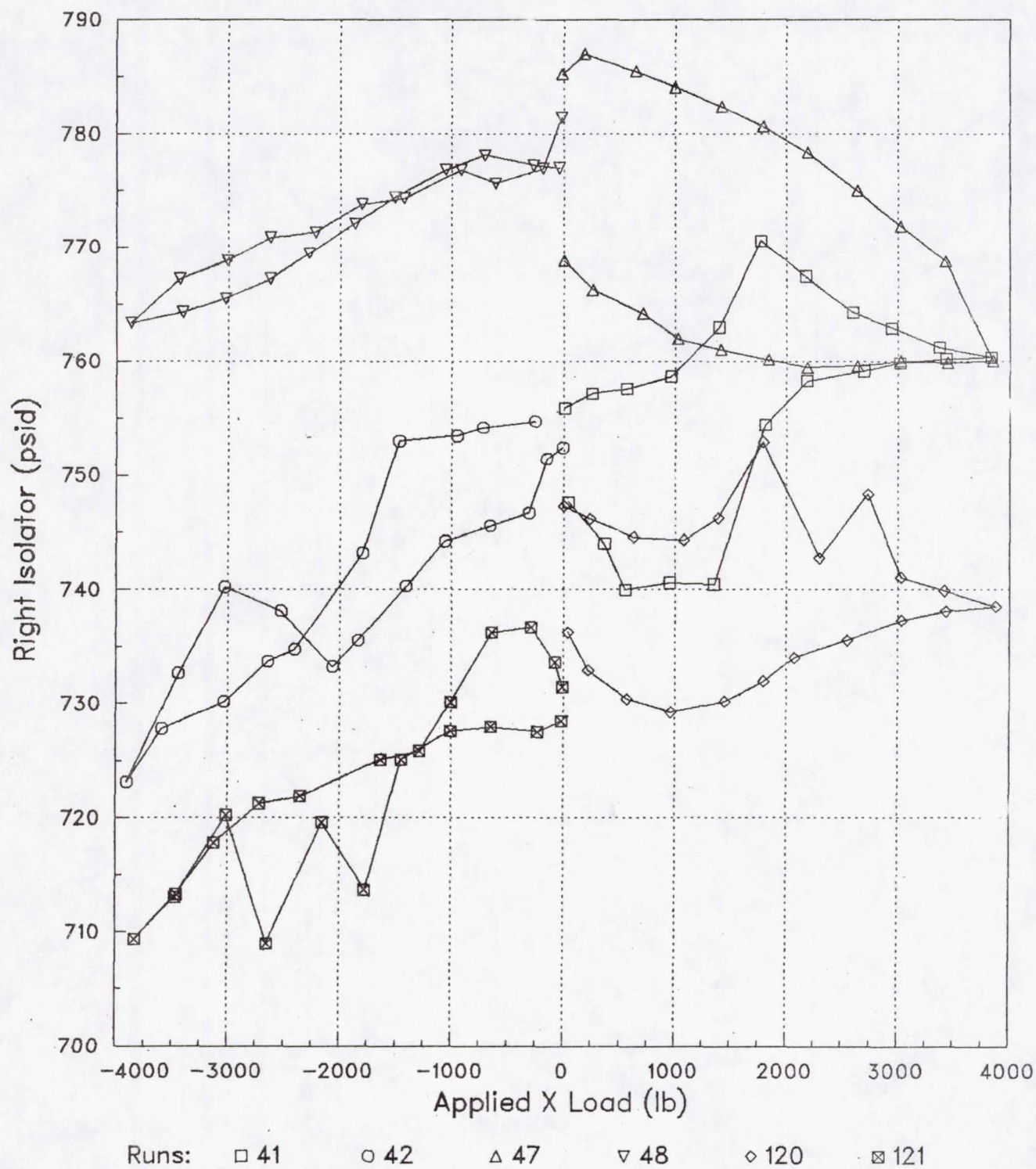
Applied X Load

Constant Loads: Z, 85% N



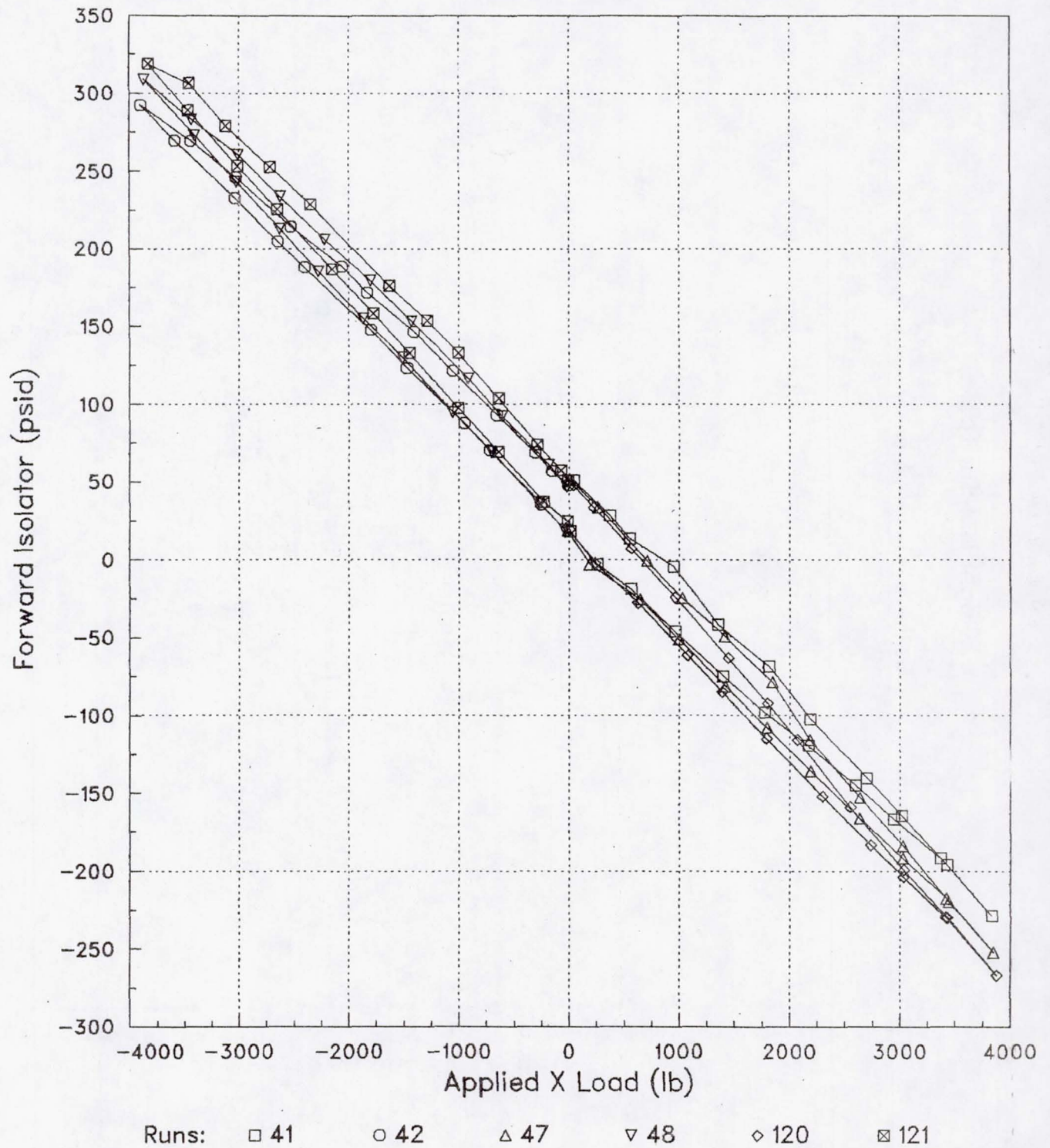
RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

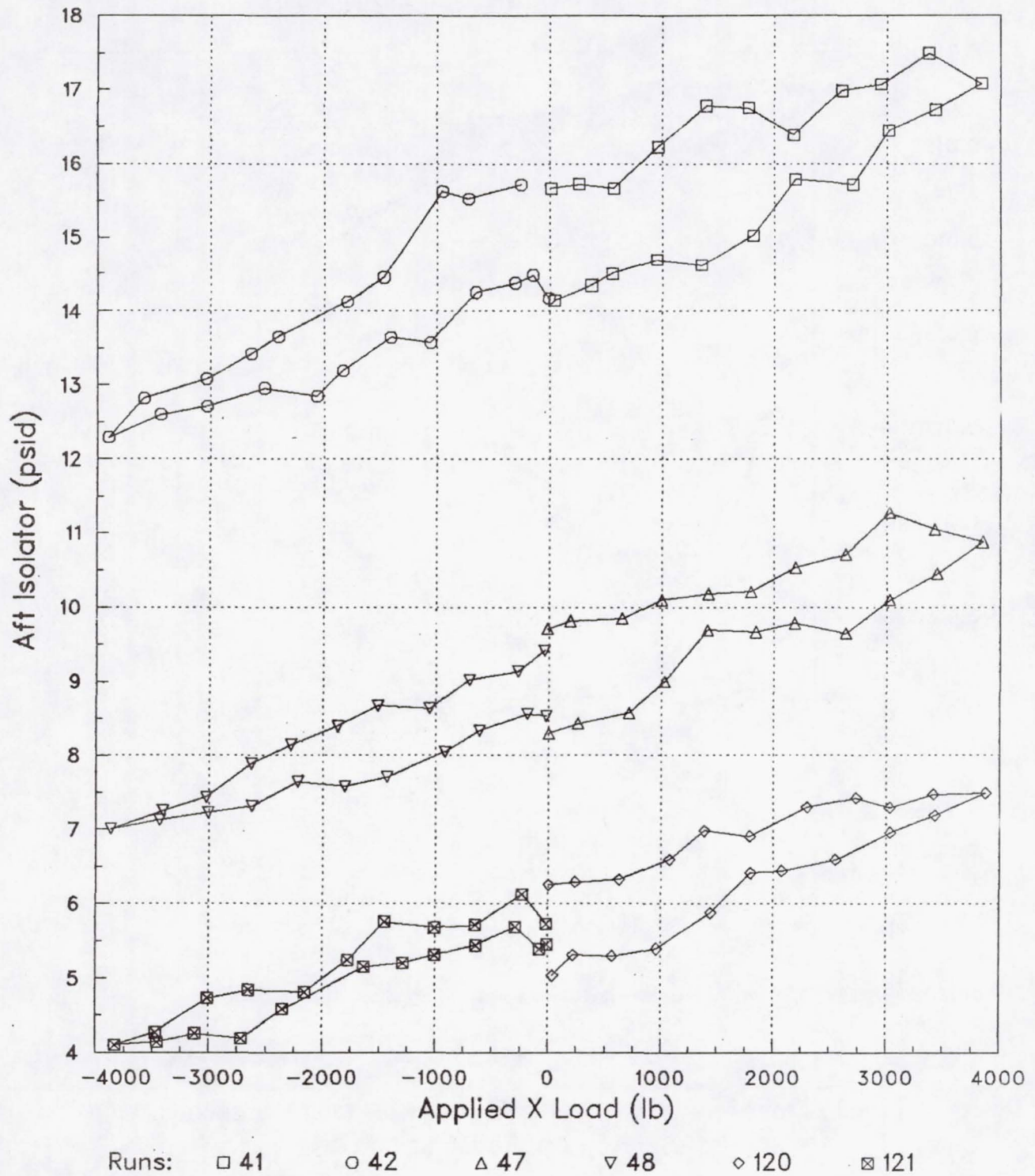
Applied X Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied X Load

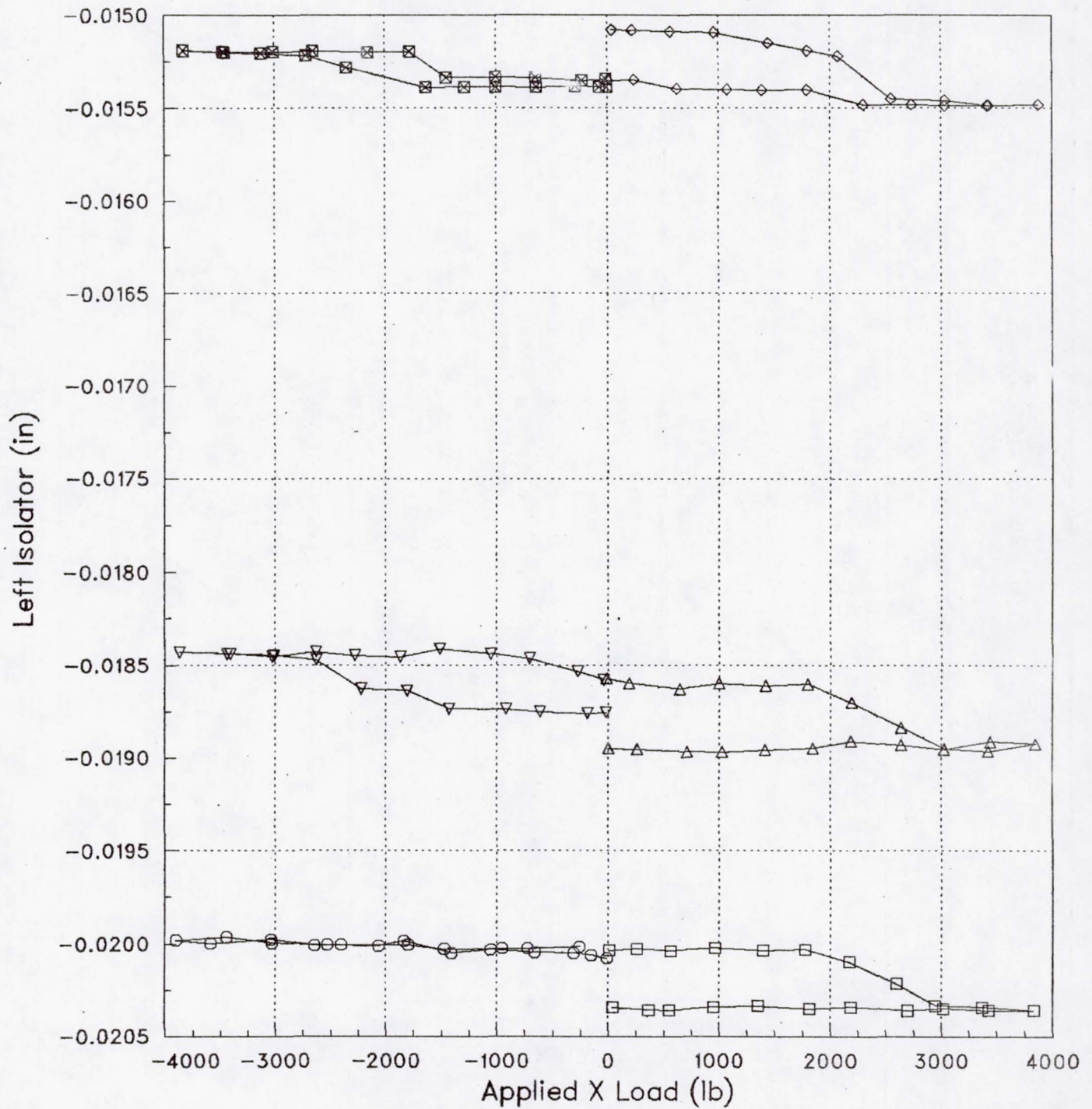
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

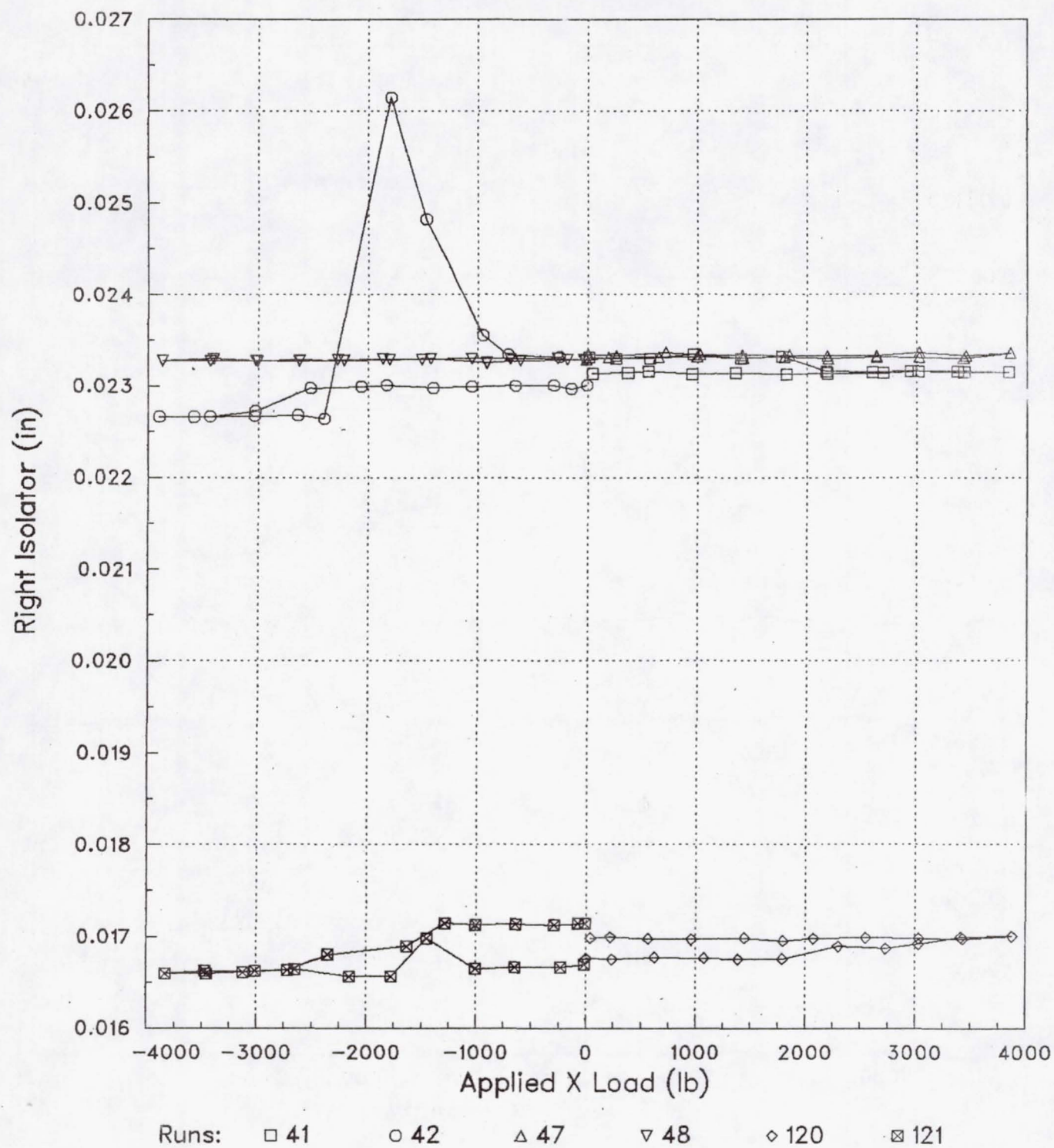
Applied X Load

Constant Loads: Z, 85% N



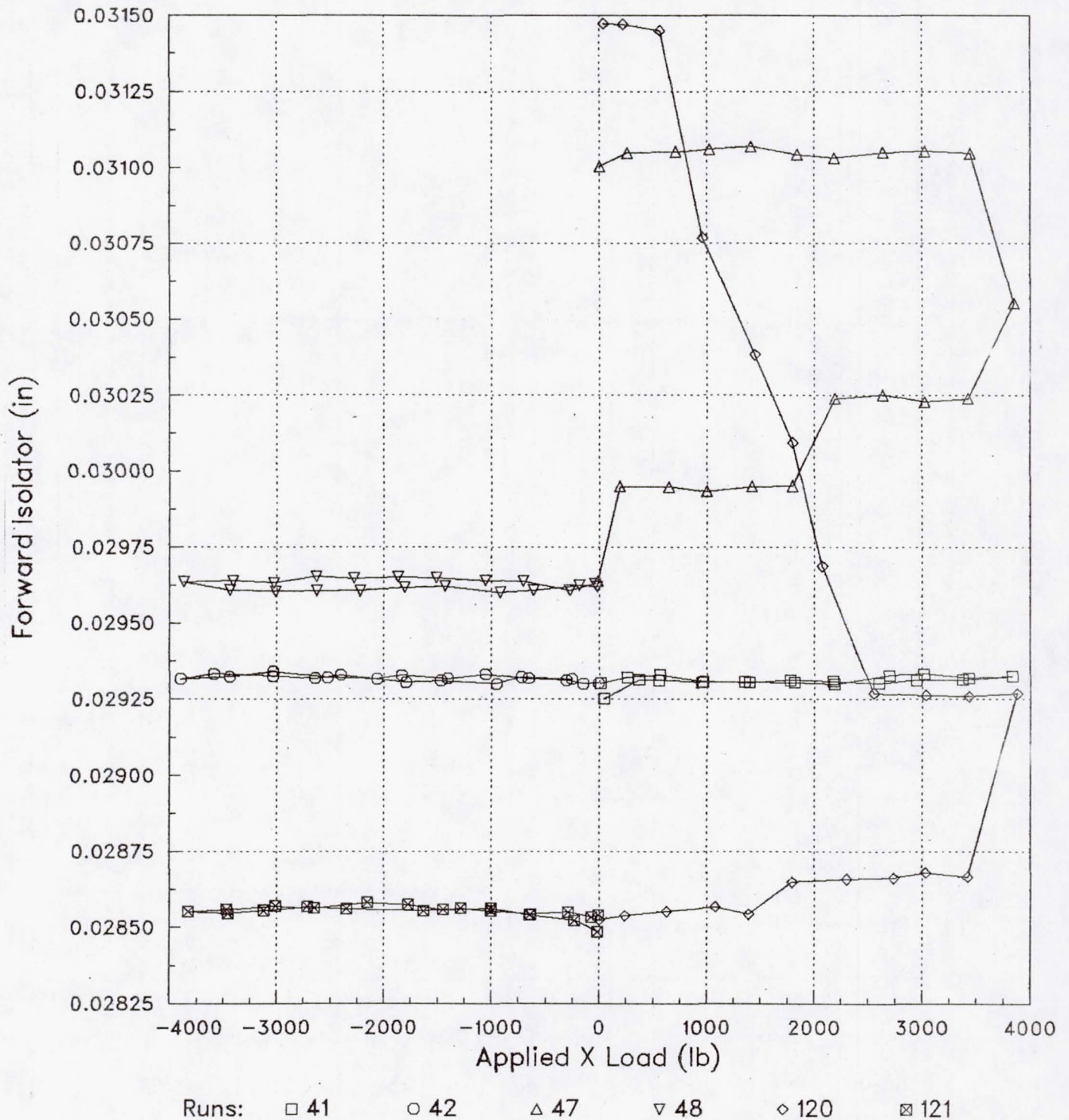
RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: Z, 85% N



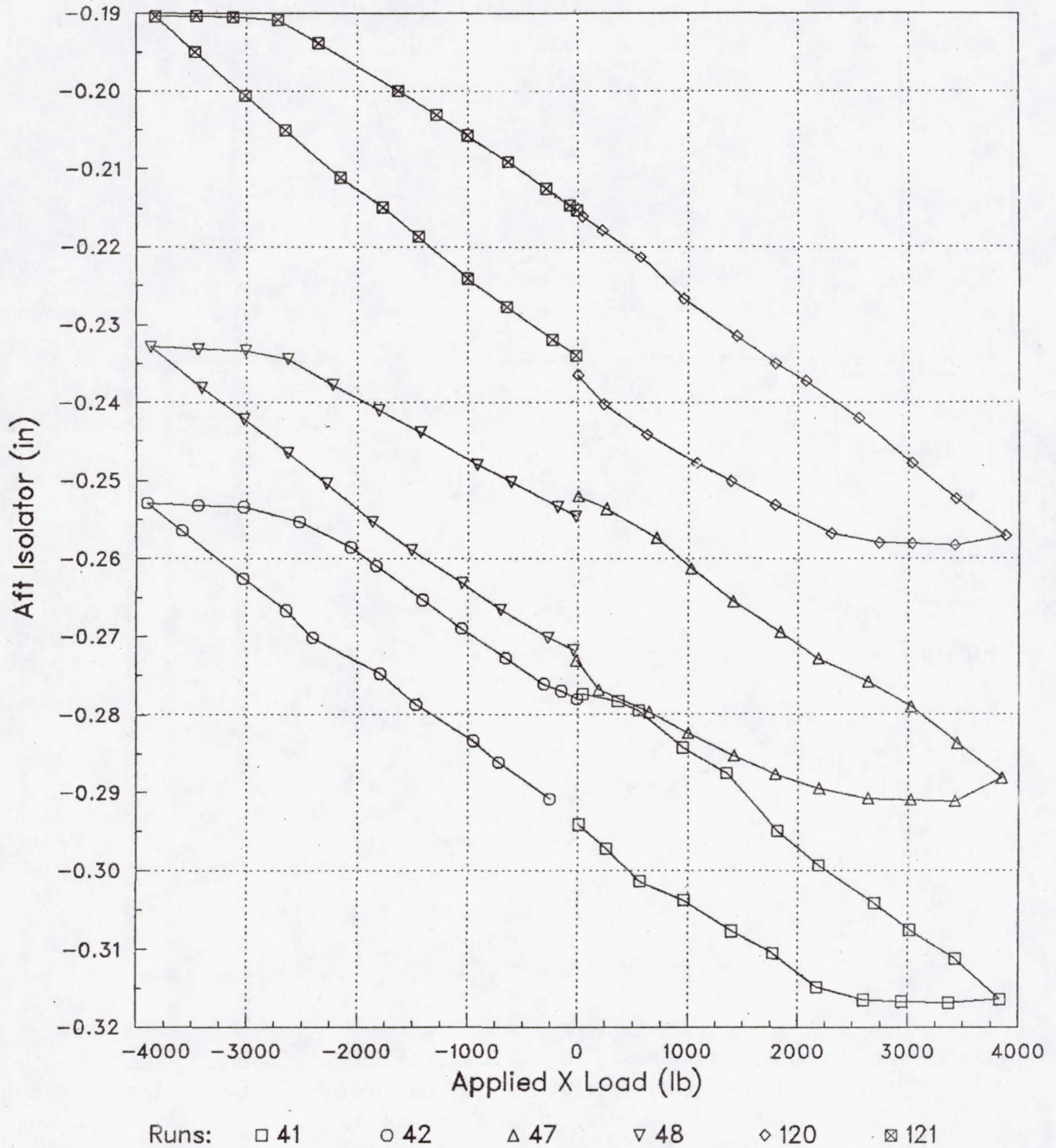
RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: Z, 85% N



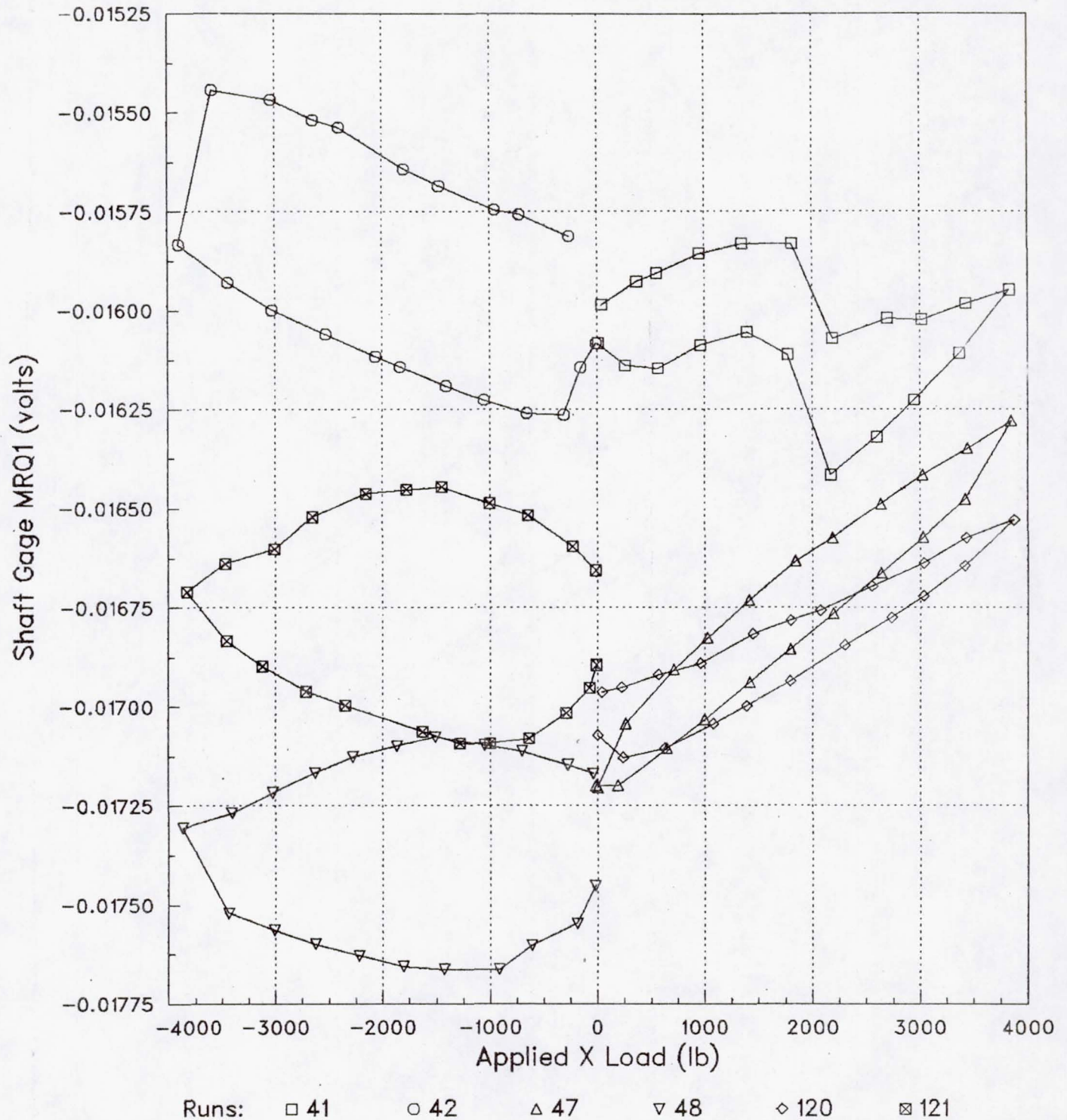
RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

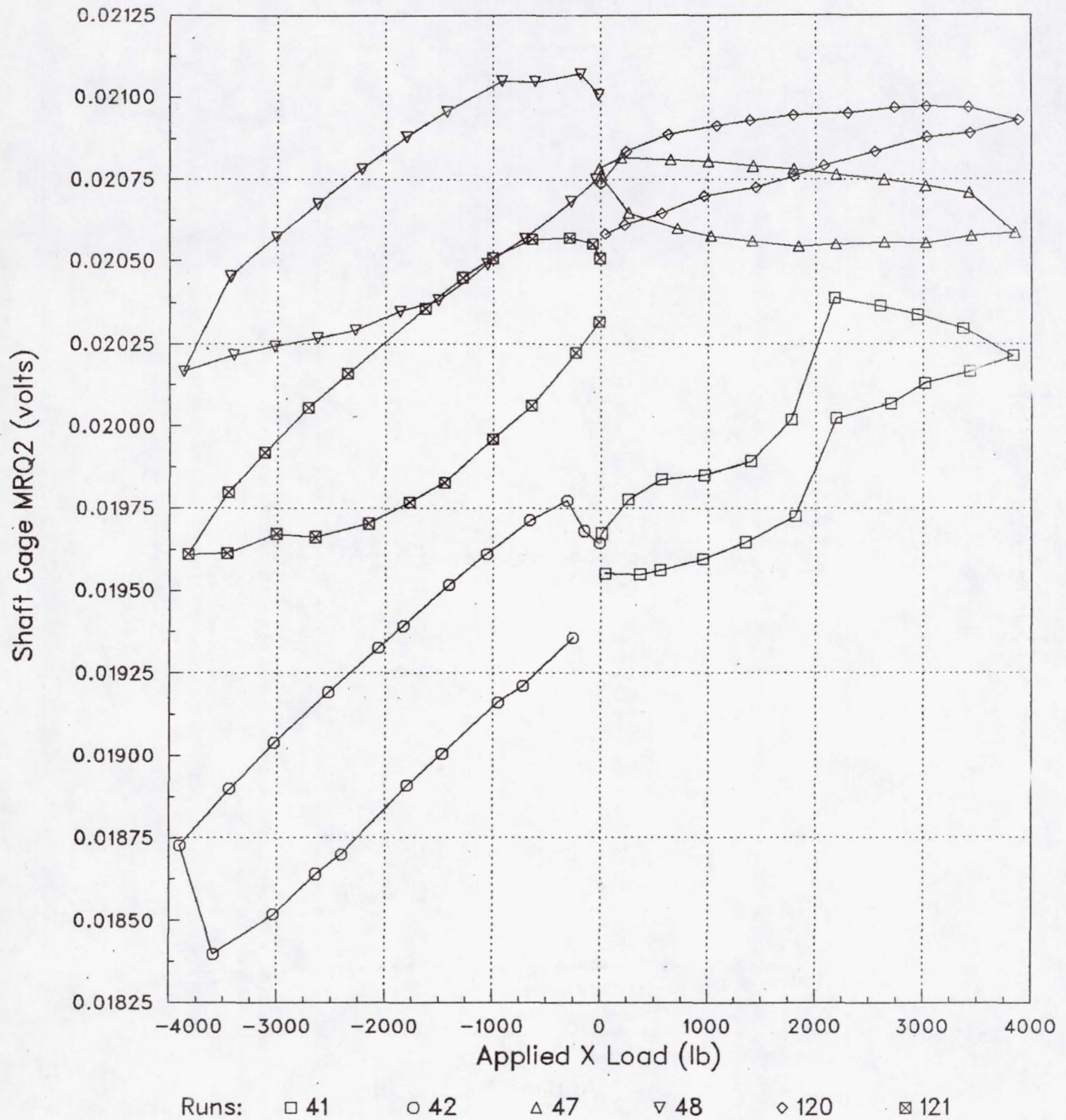
Applied X Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

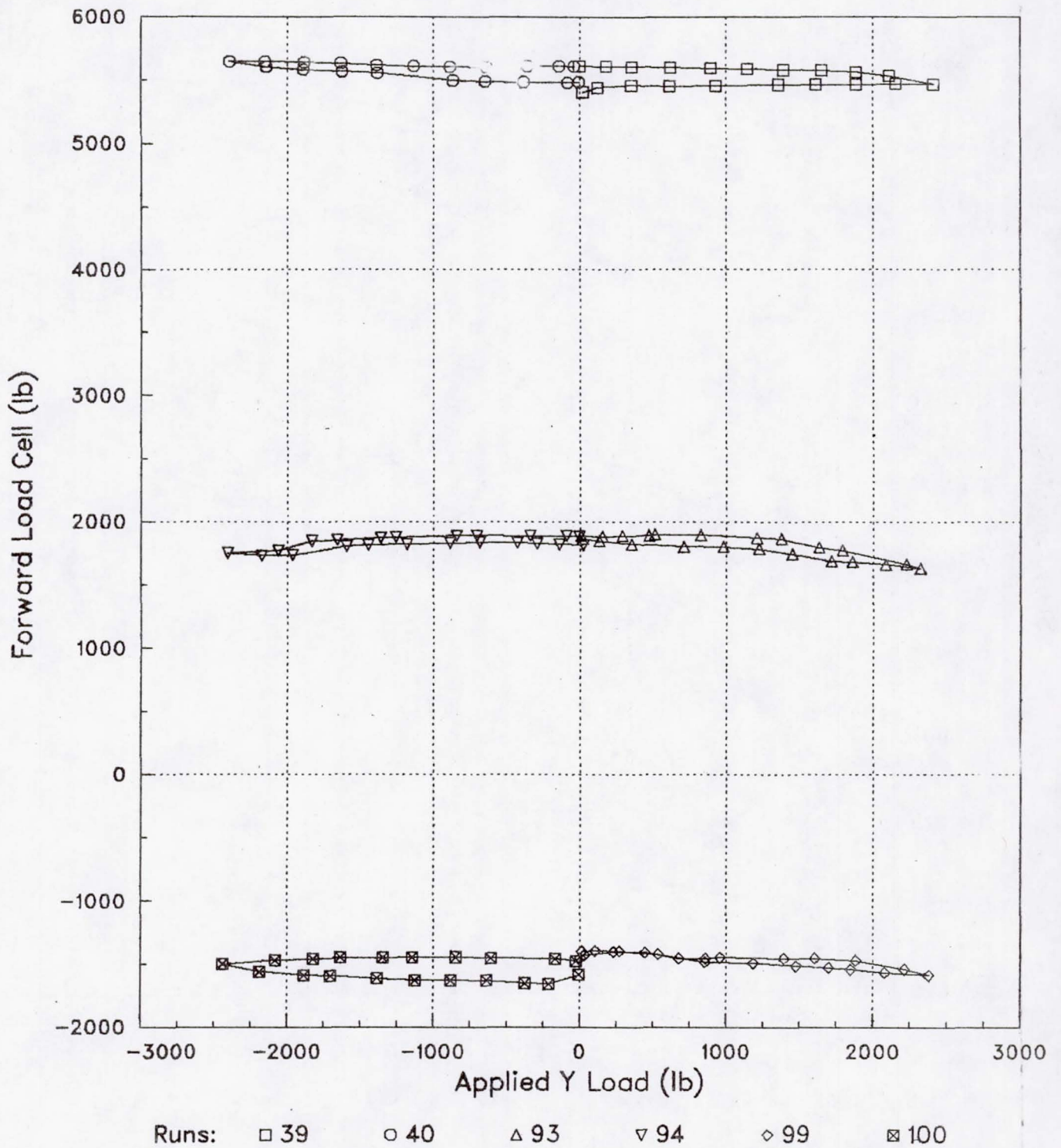
Applied X Load

Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

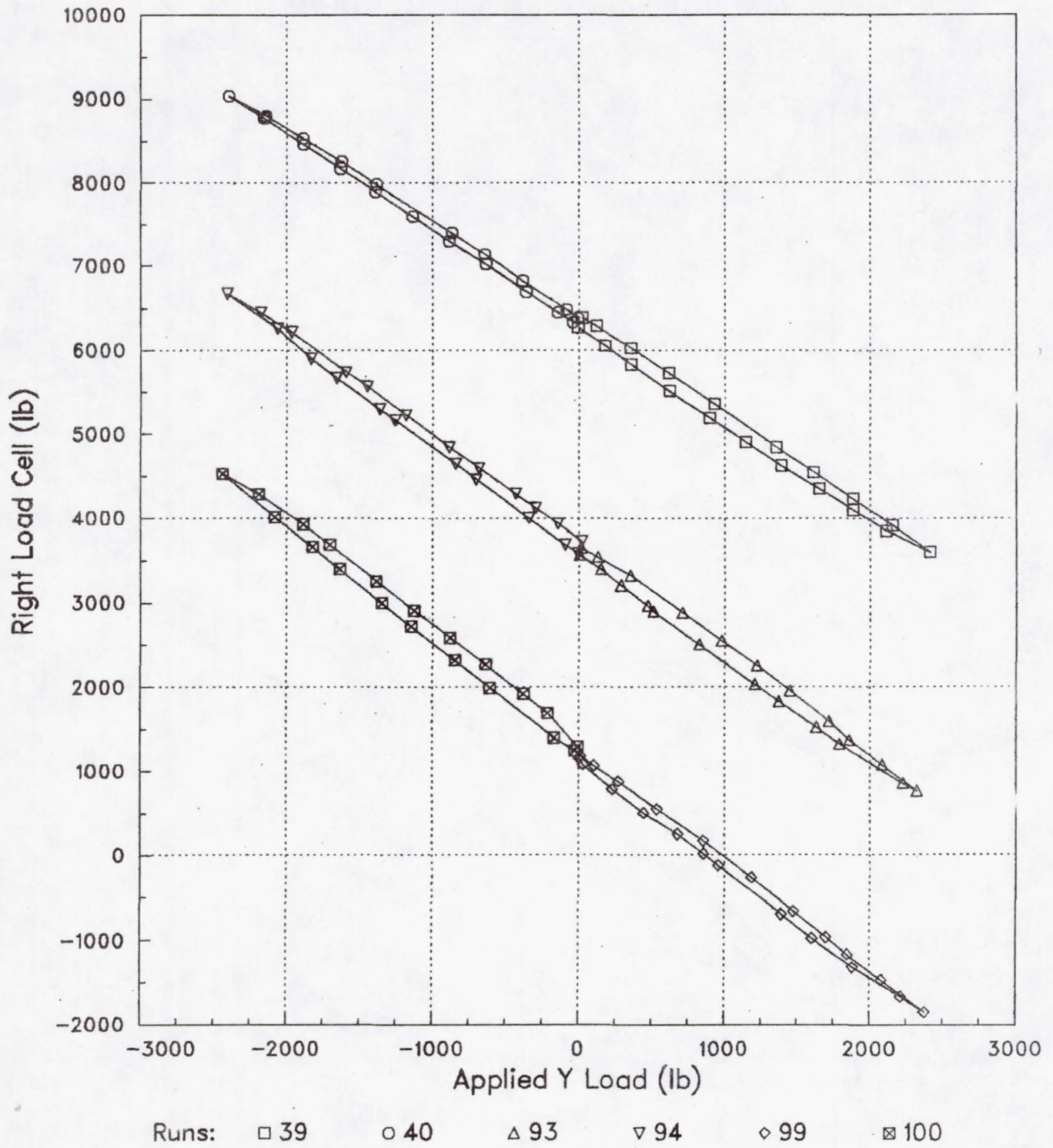
Applied Y Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load

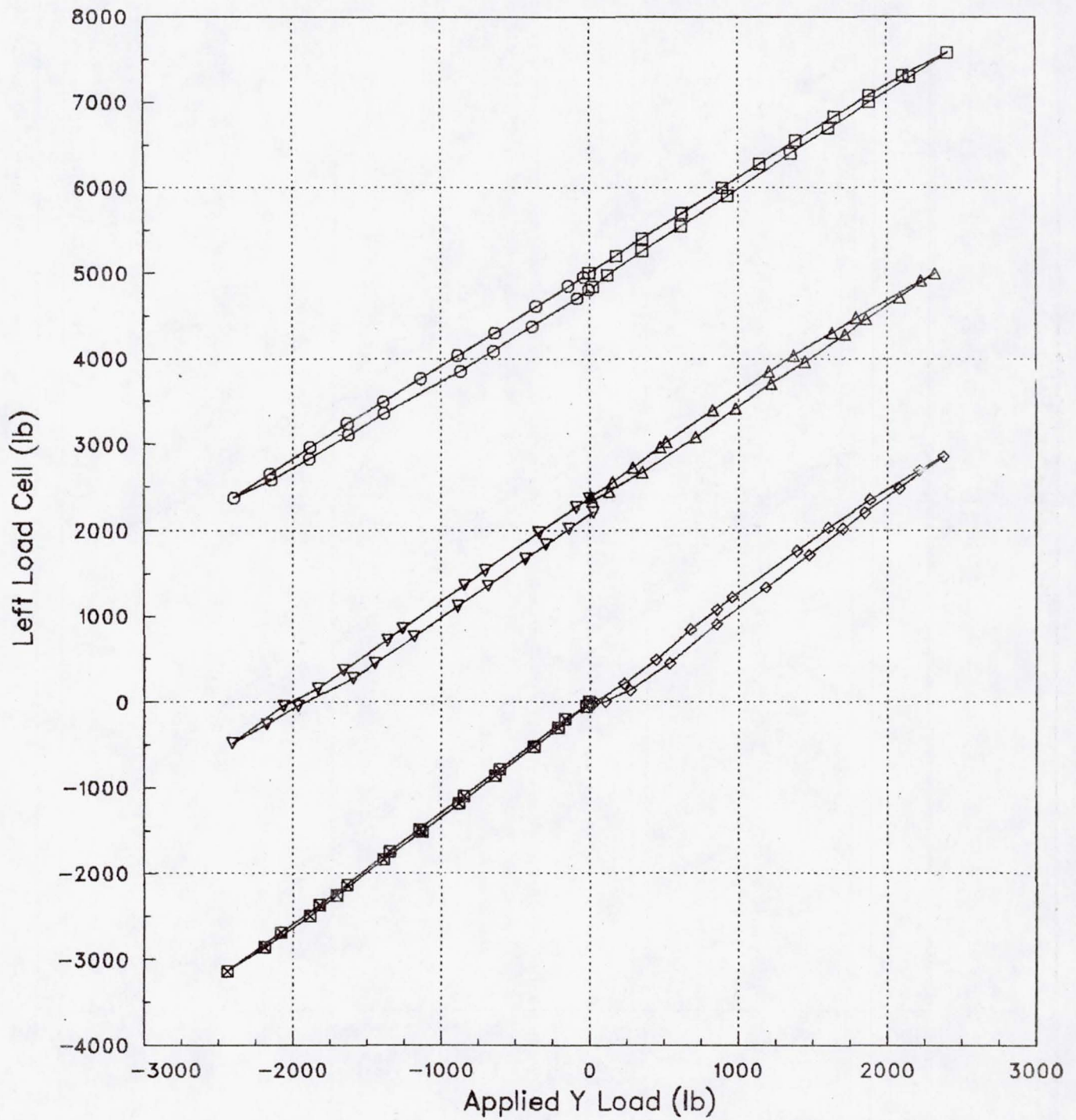
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load

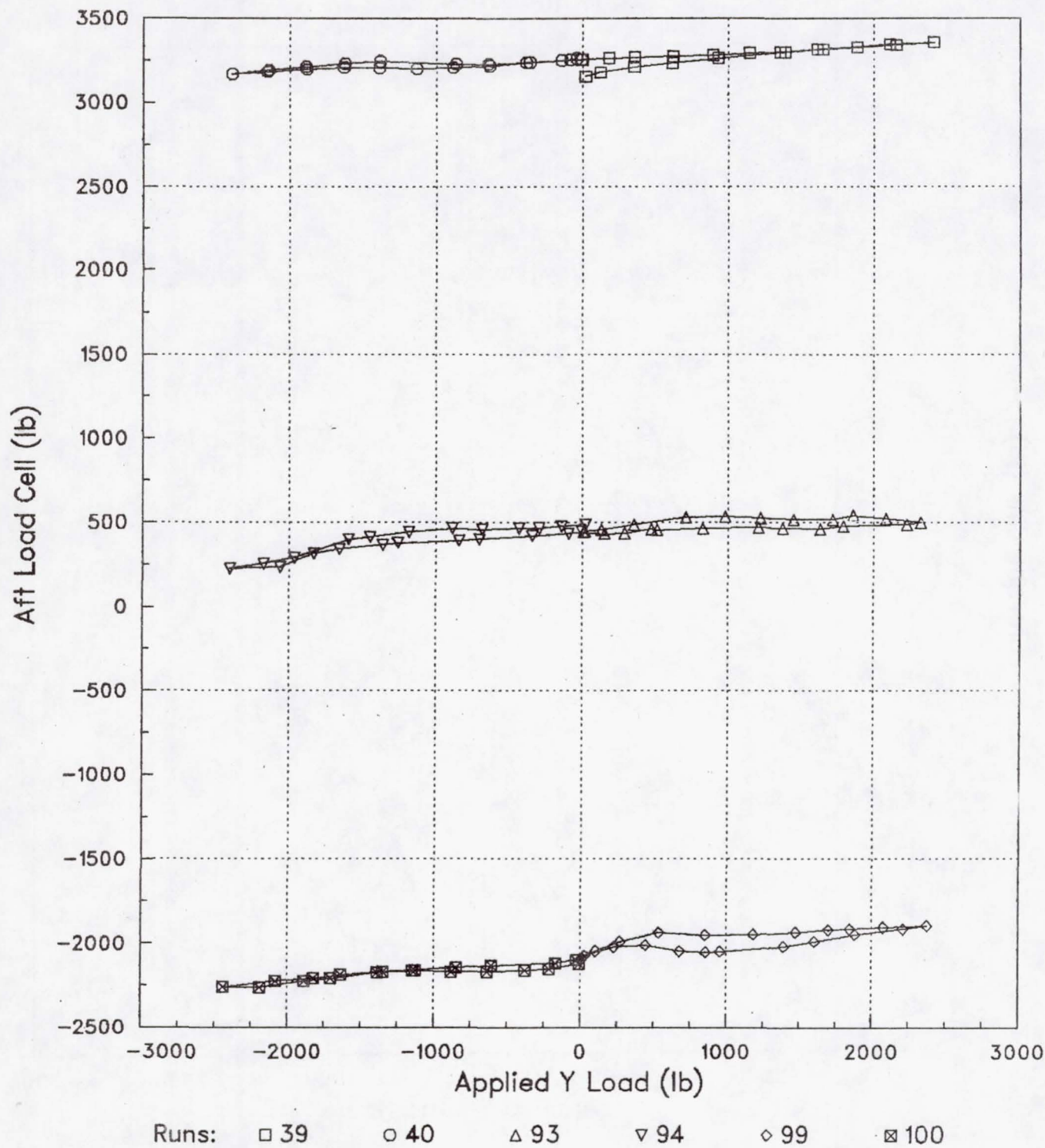
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

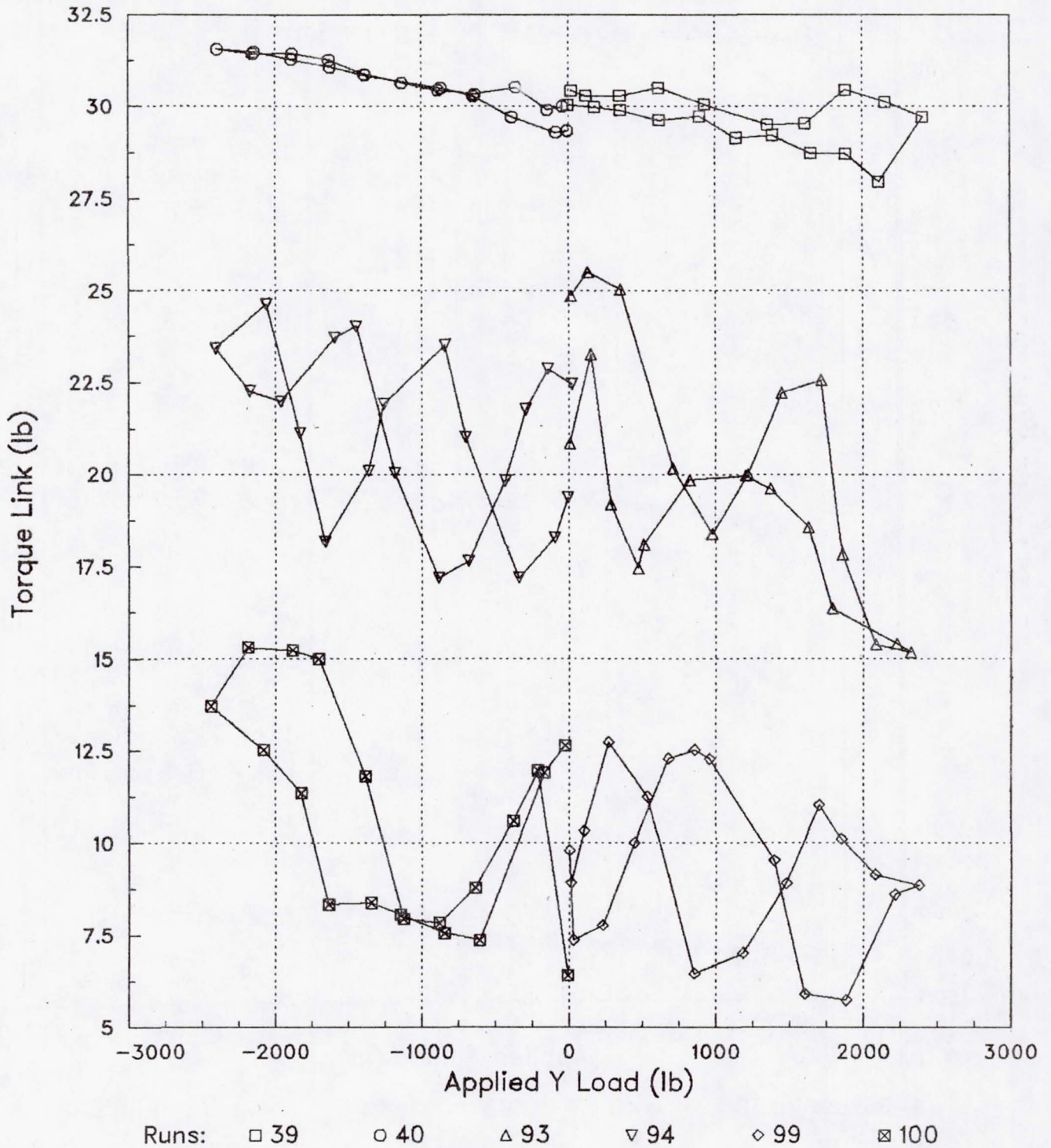
Applied Y Load

Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

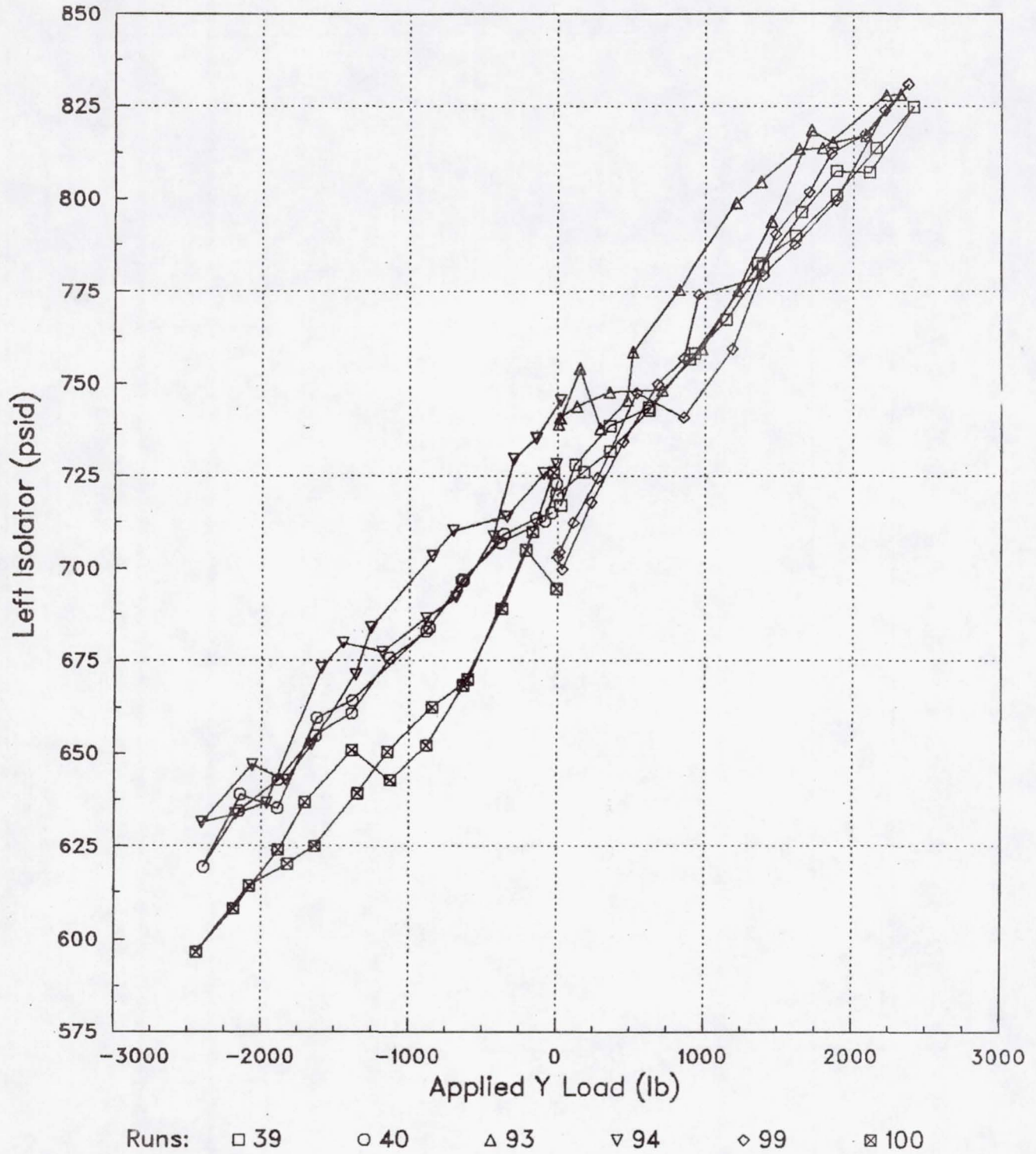
Applied Y Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

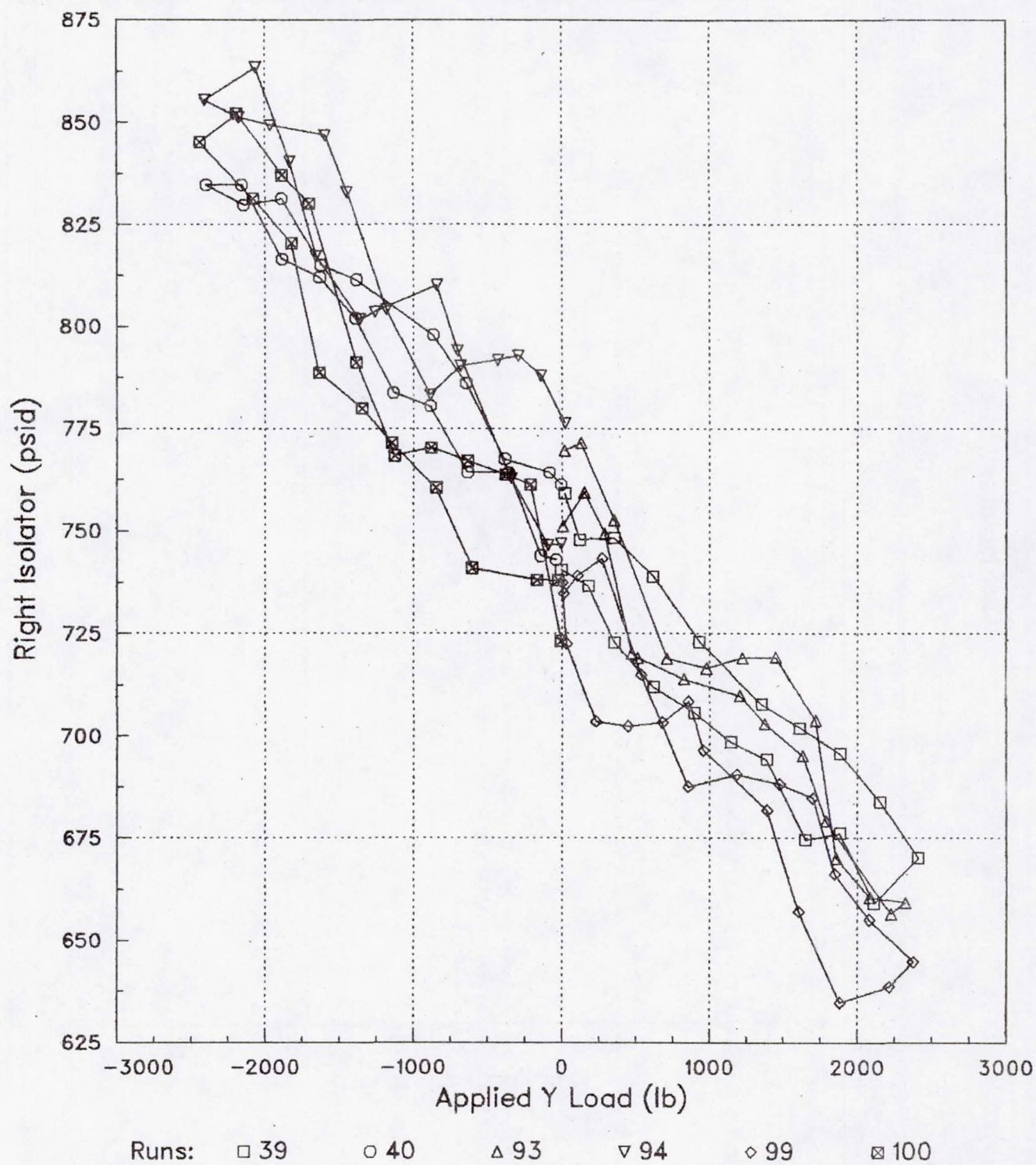
Applied Y Load

Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

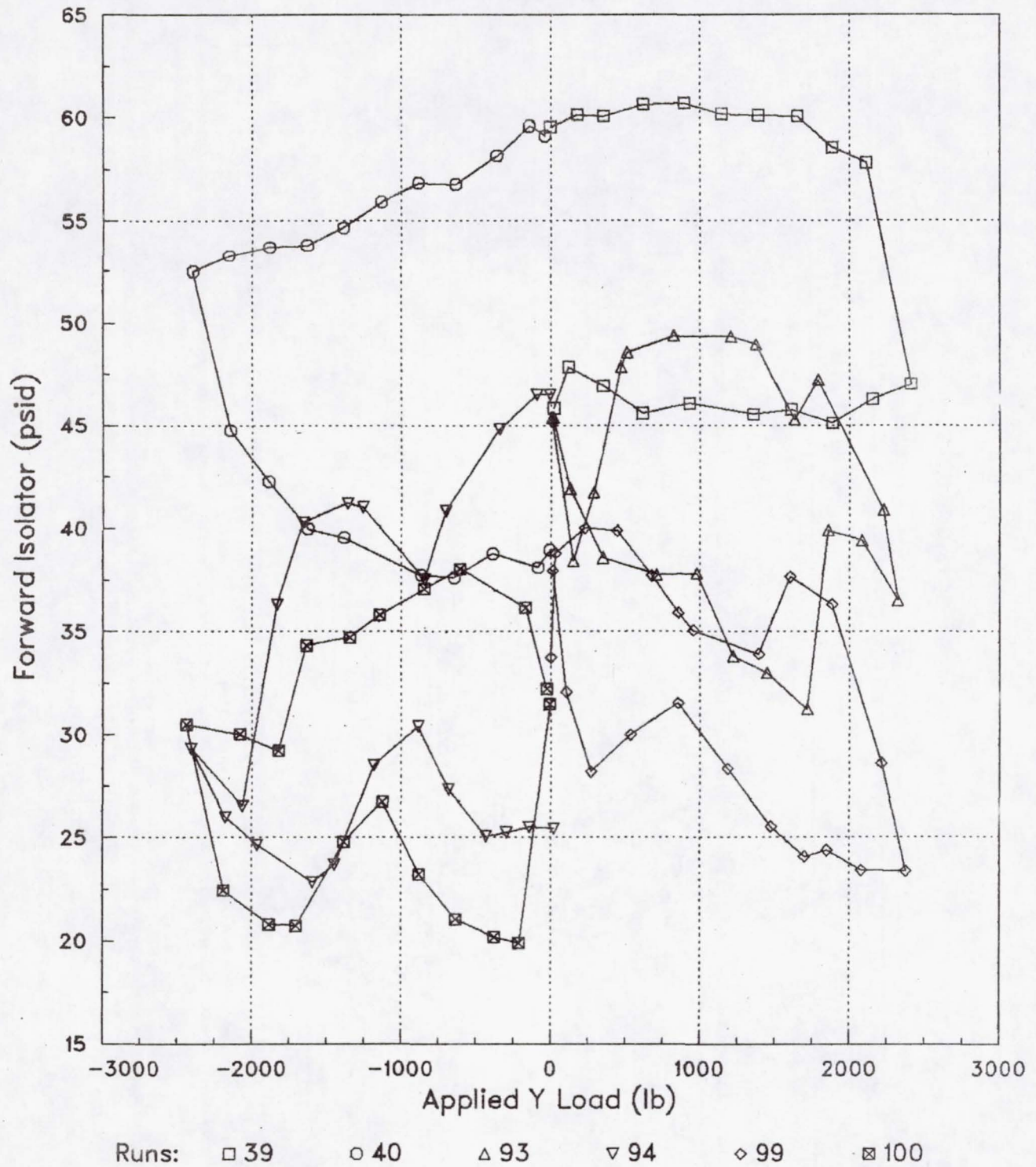
Applied Y Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

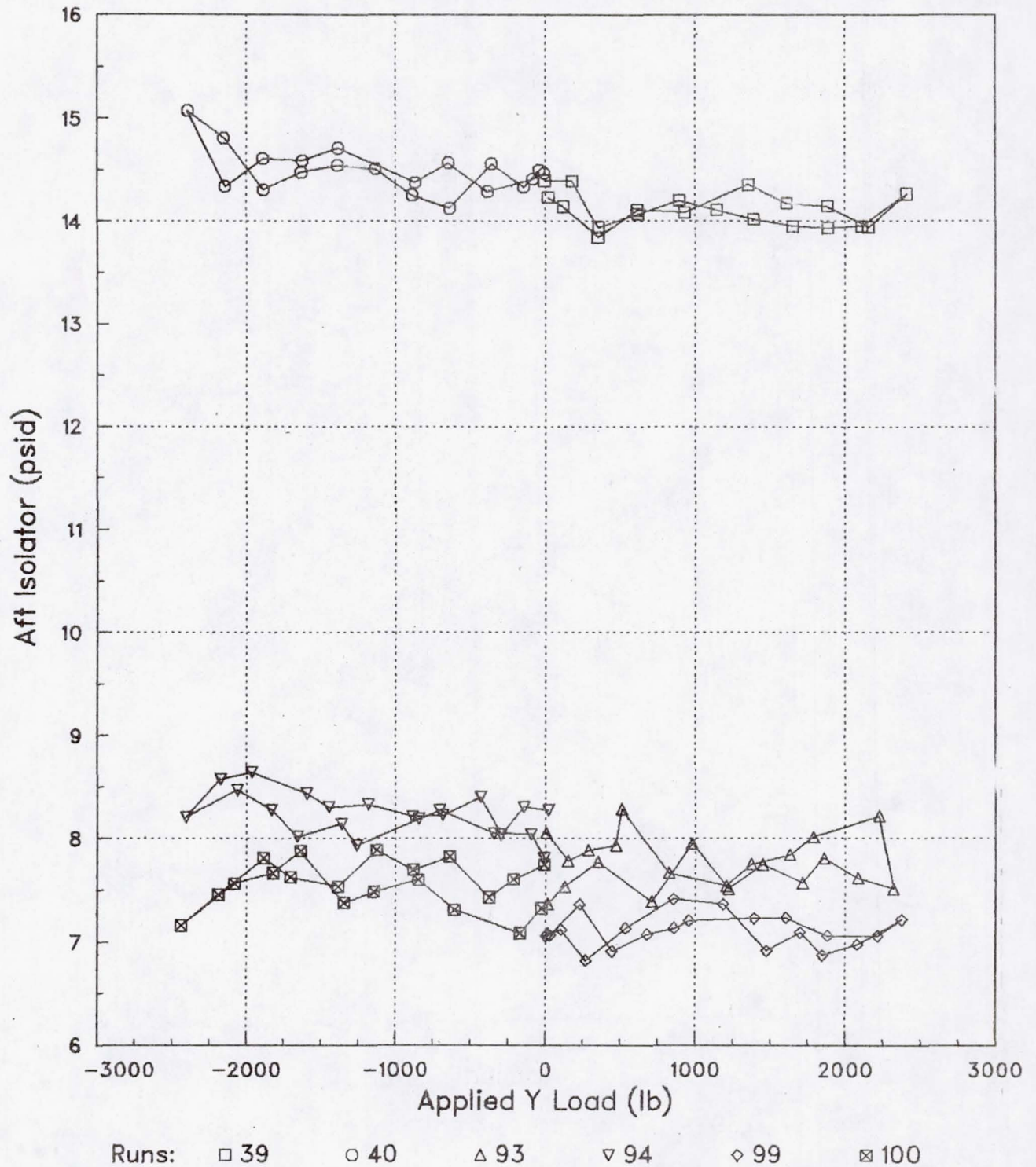
Applied Y Load

Constant Loads: Z, 85% N



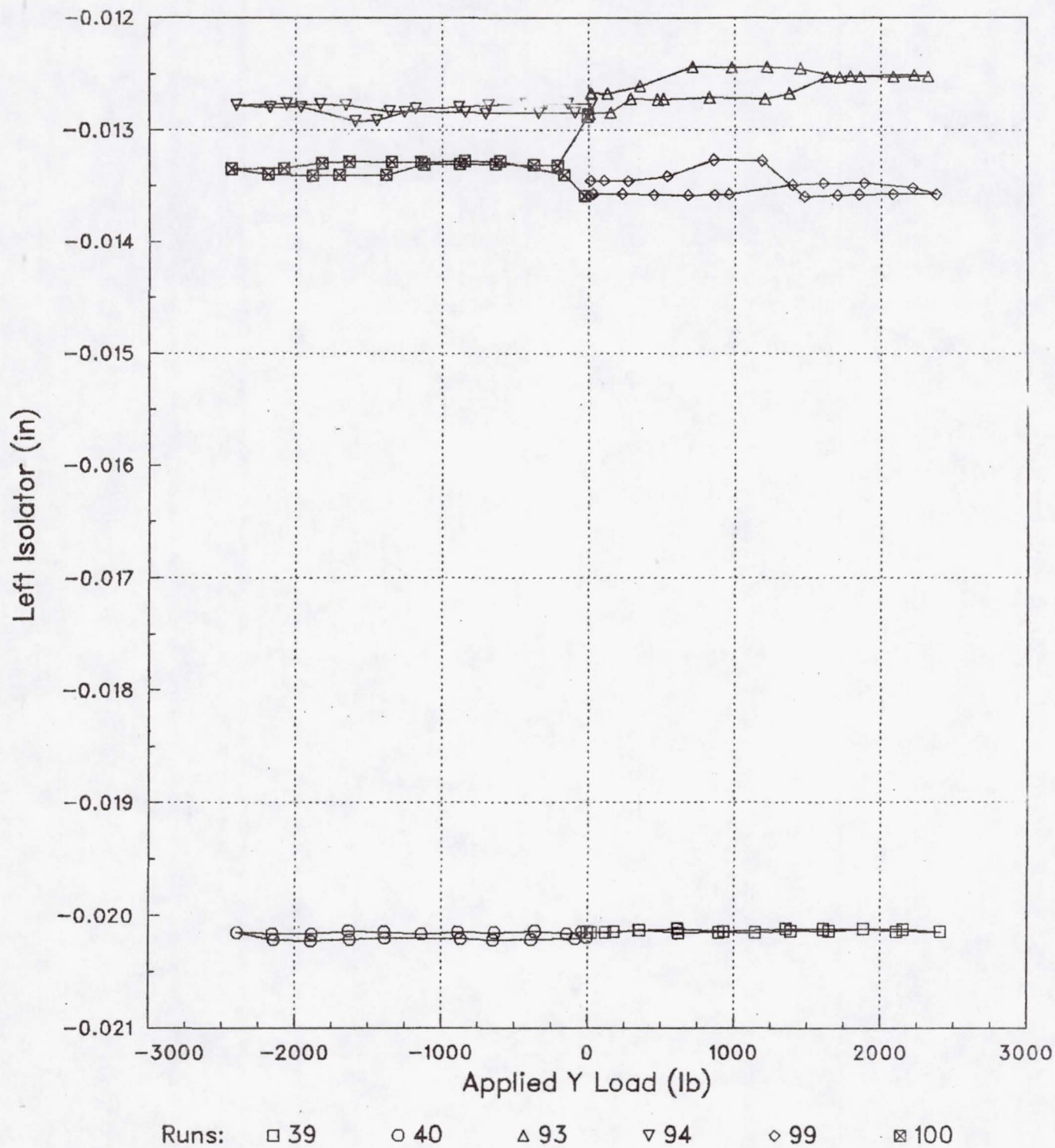
RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

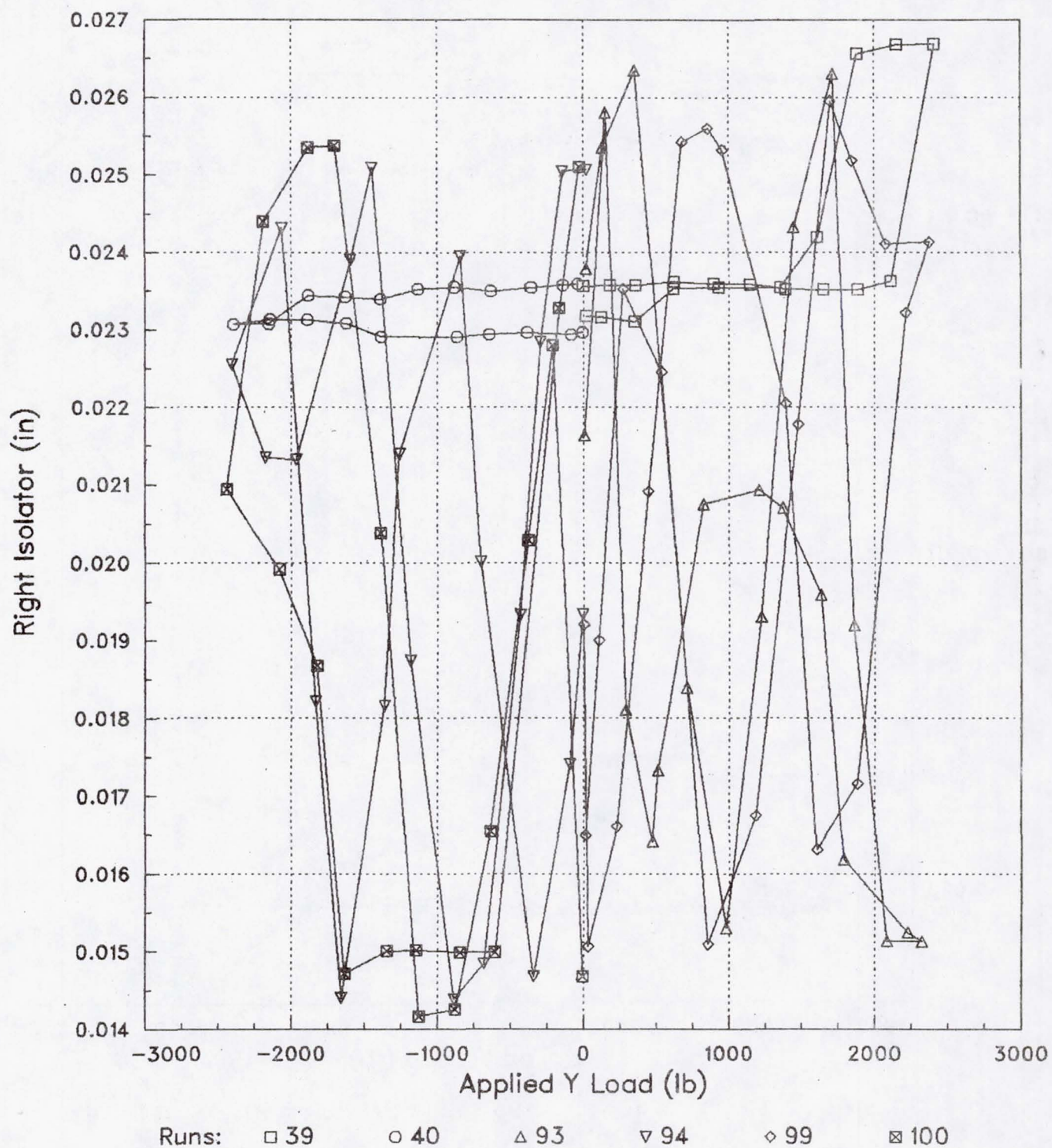
Applied Y Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load

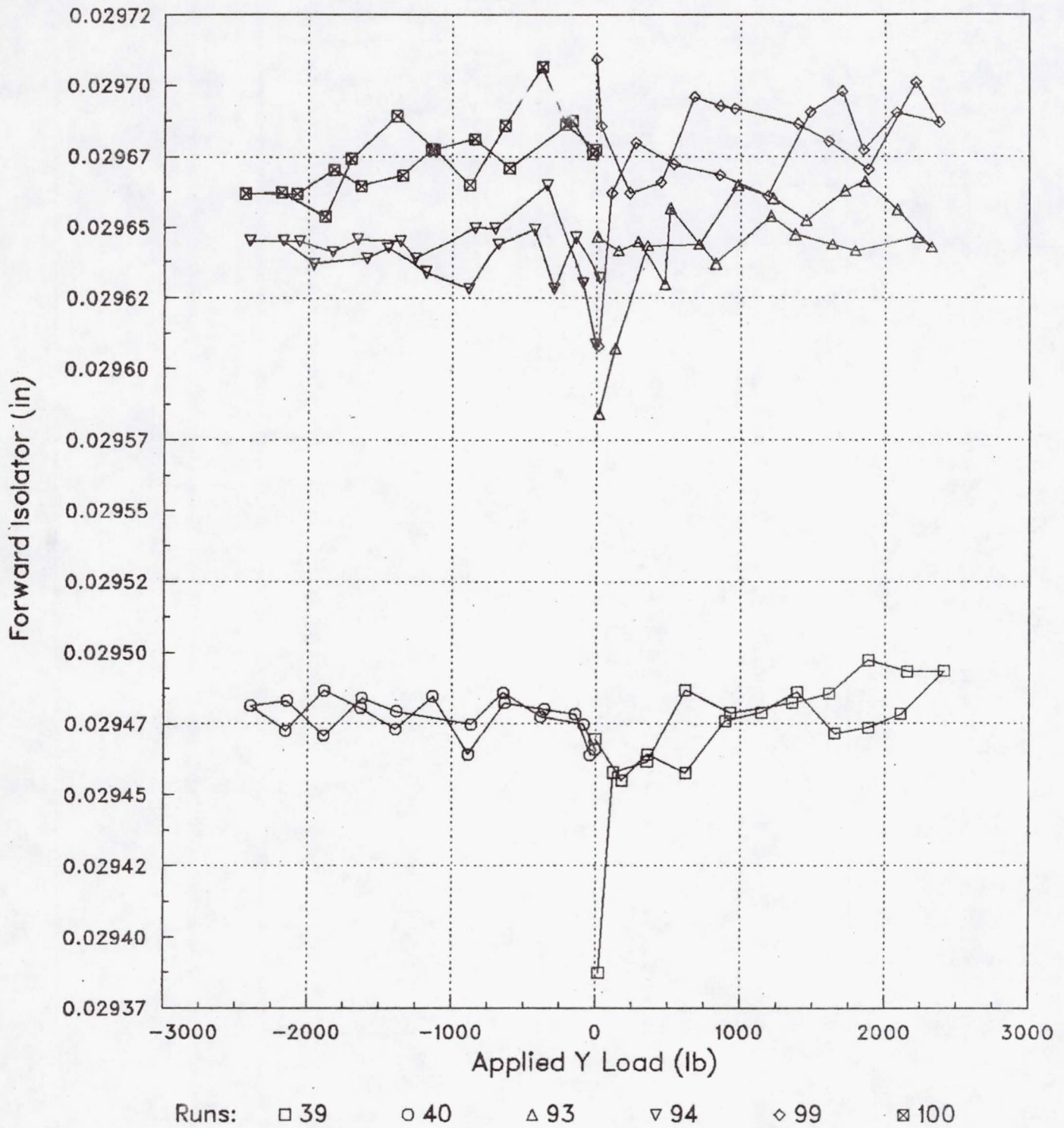
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

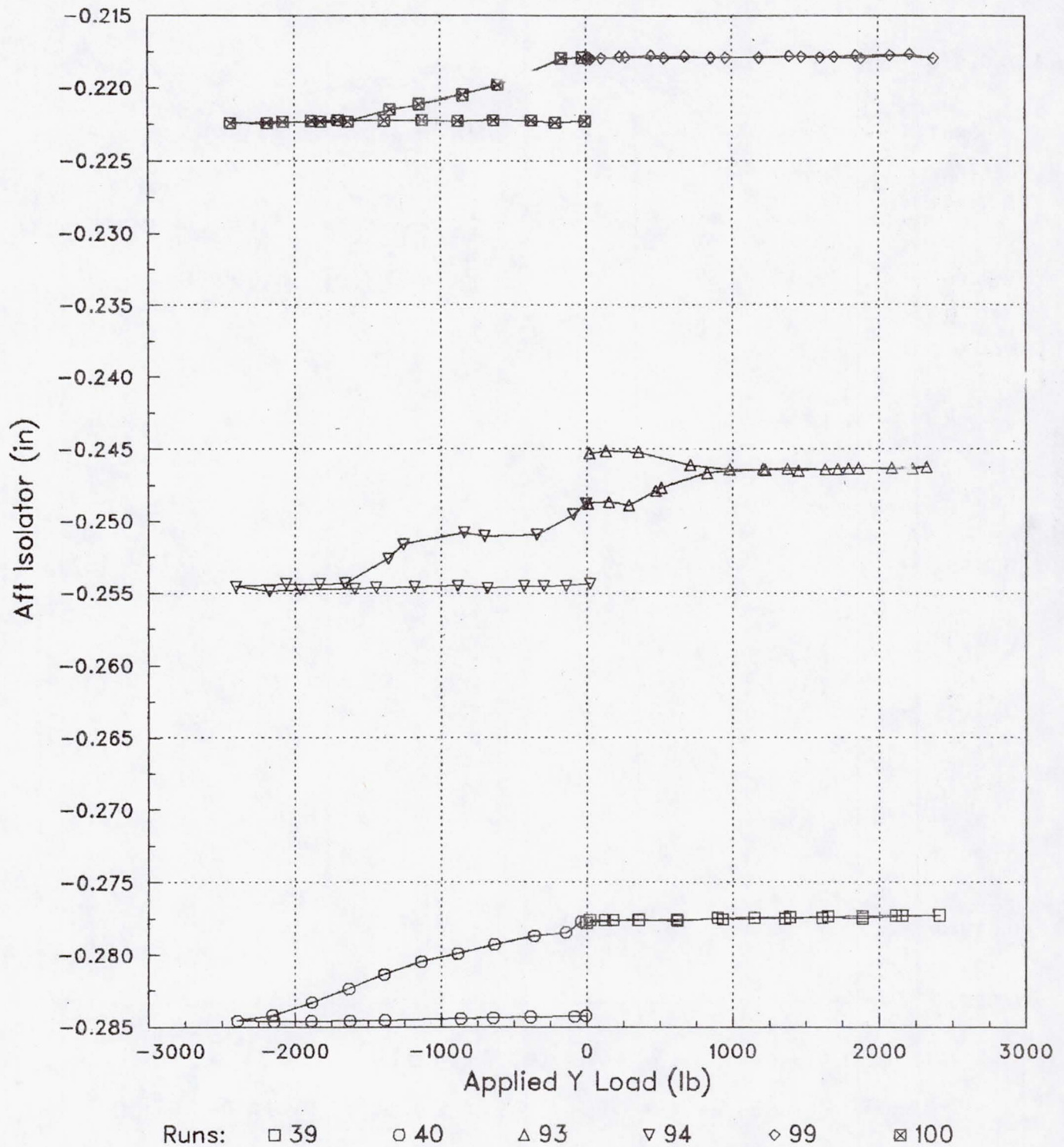
Applied Y Load

Constant Loads: *Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

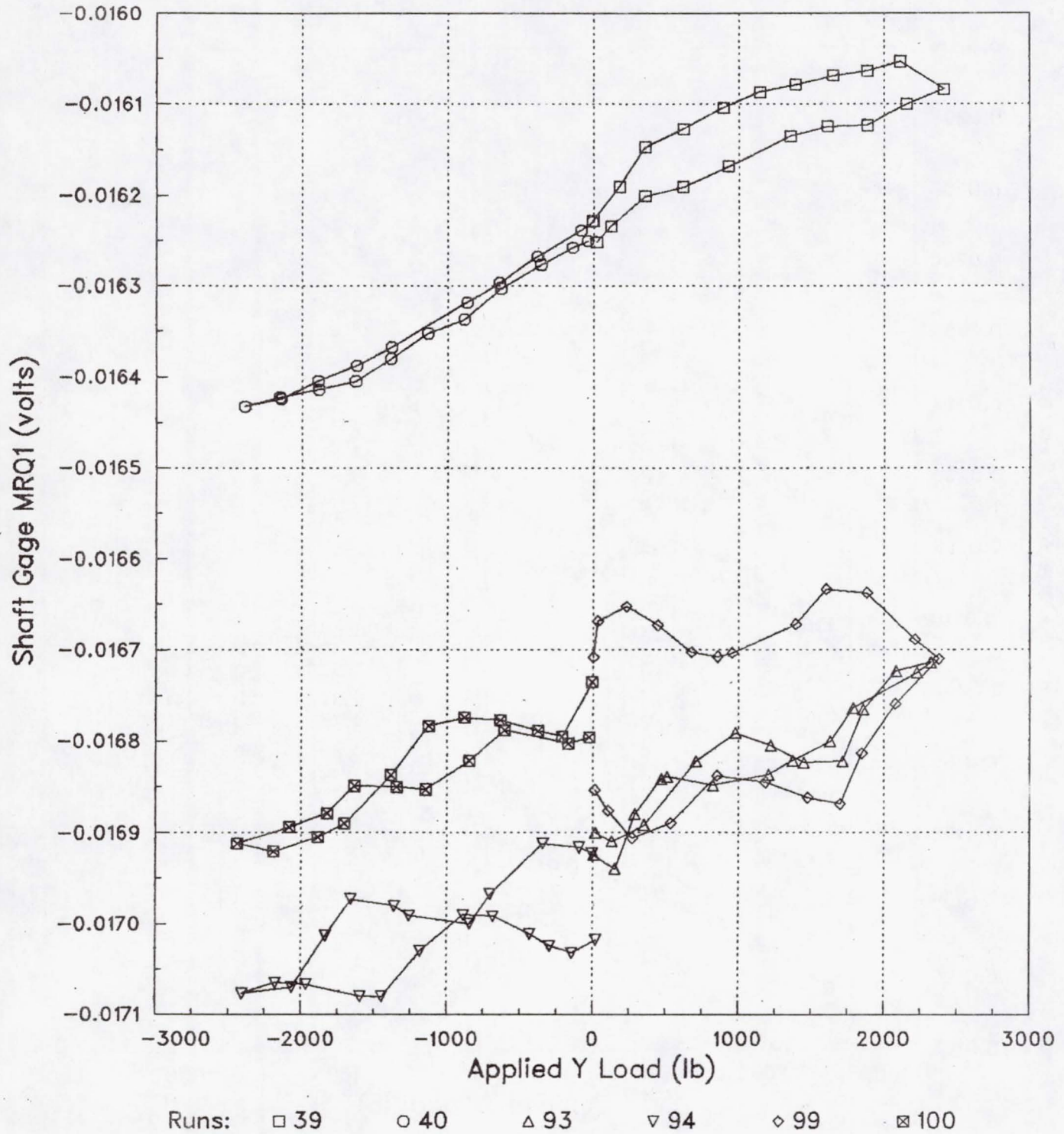
Applied Y Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

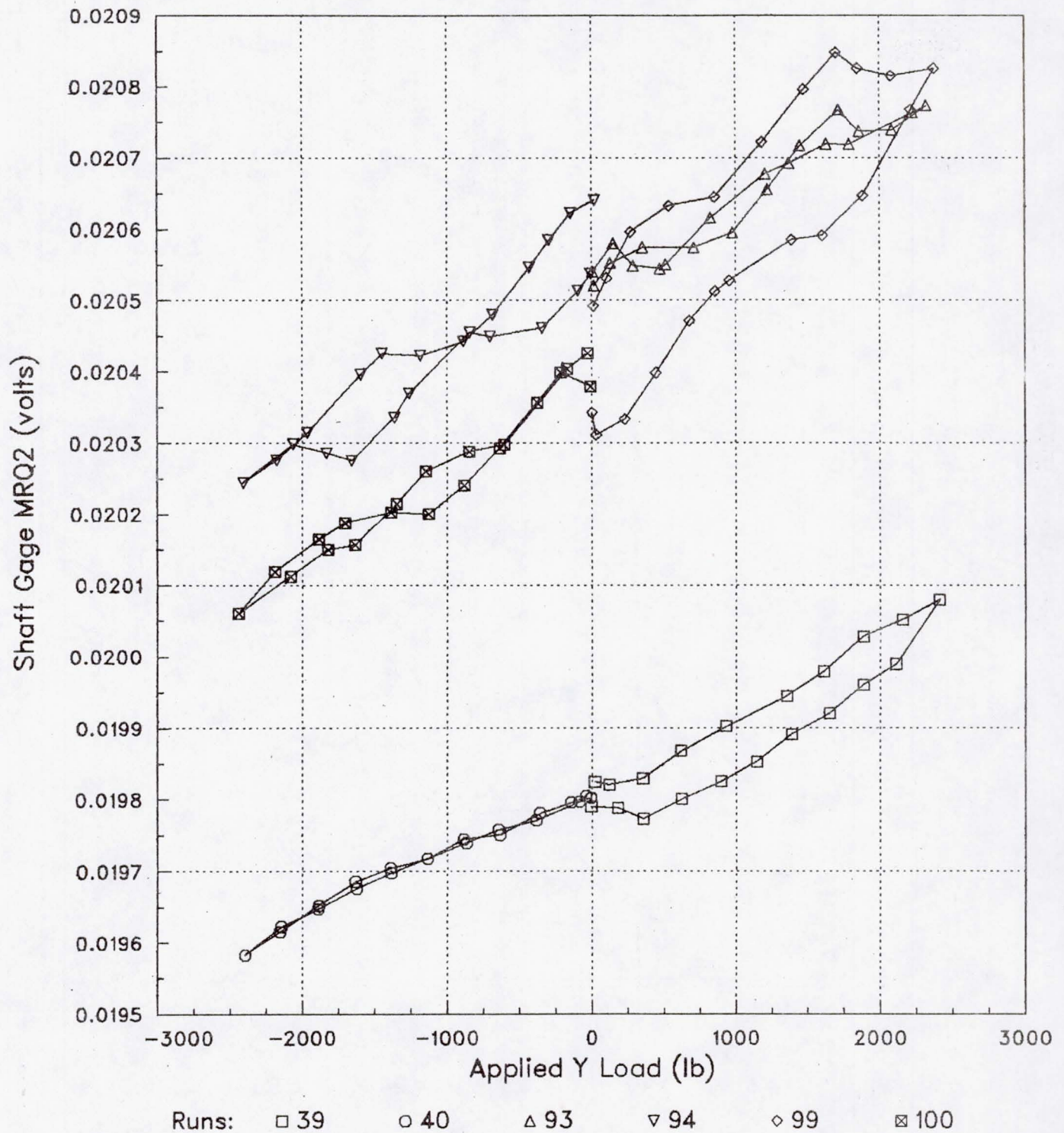
Applied Y Load

Constant Loads: Z, 85% N



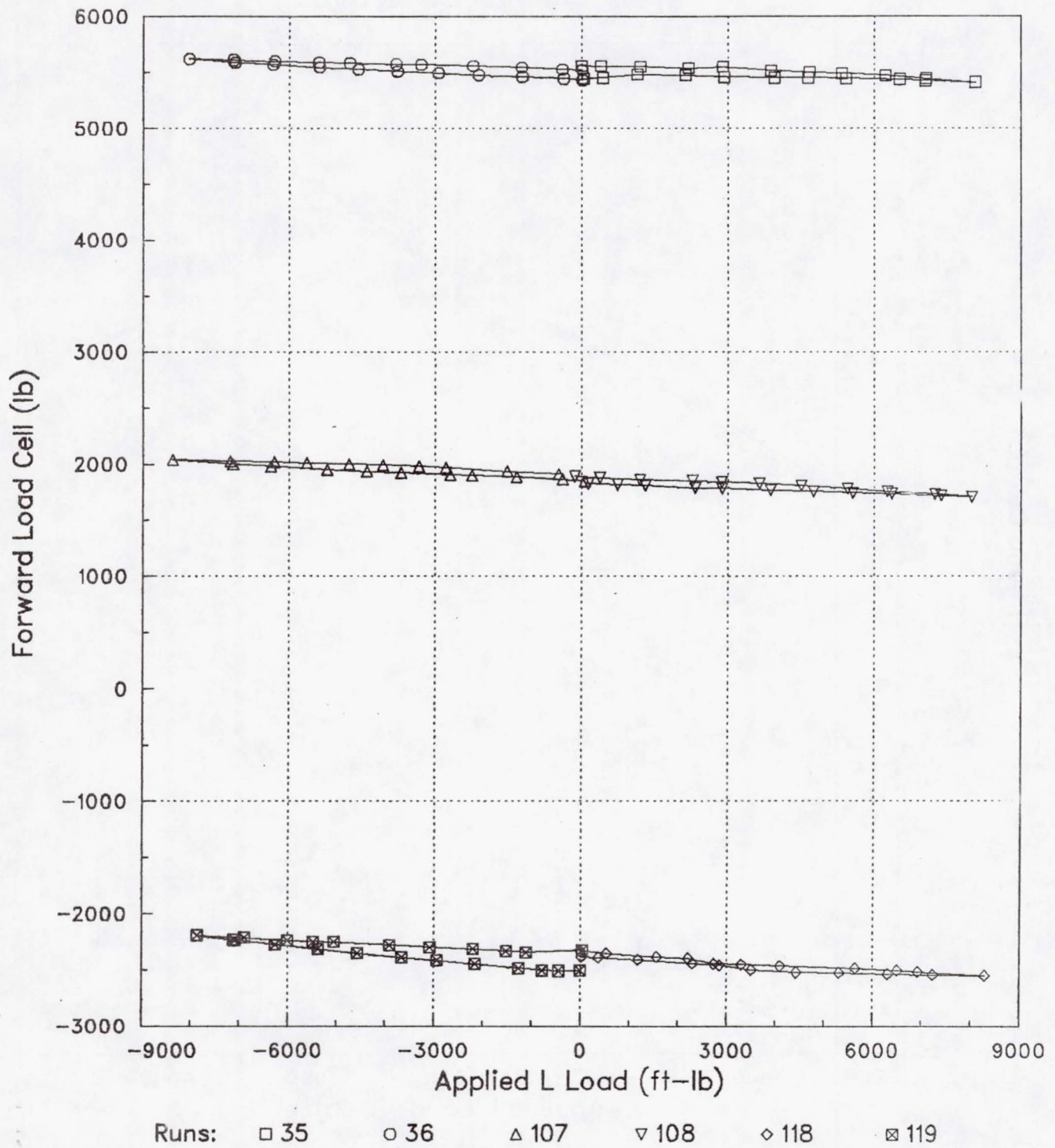
RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: Z, 85% N



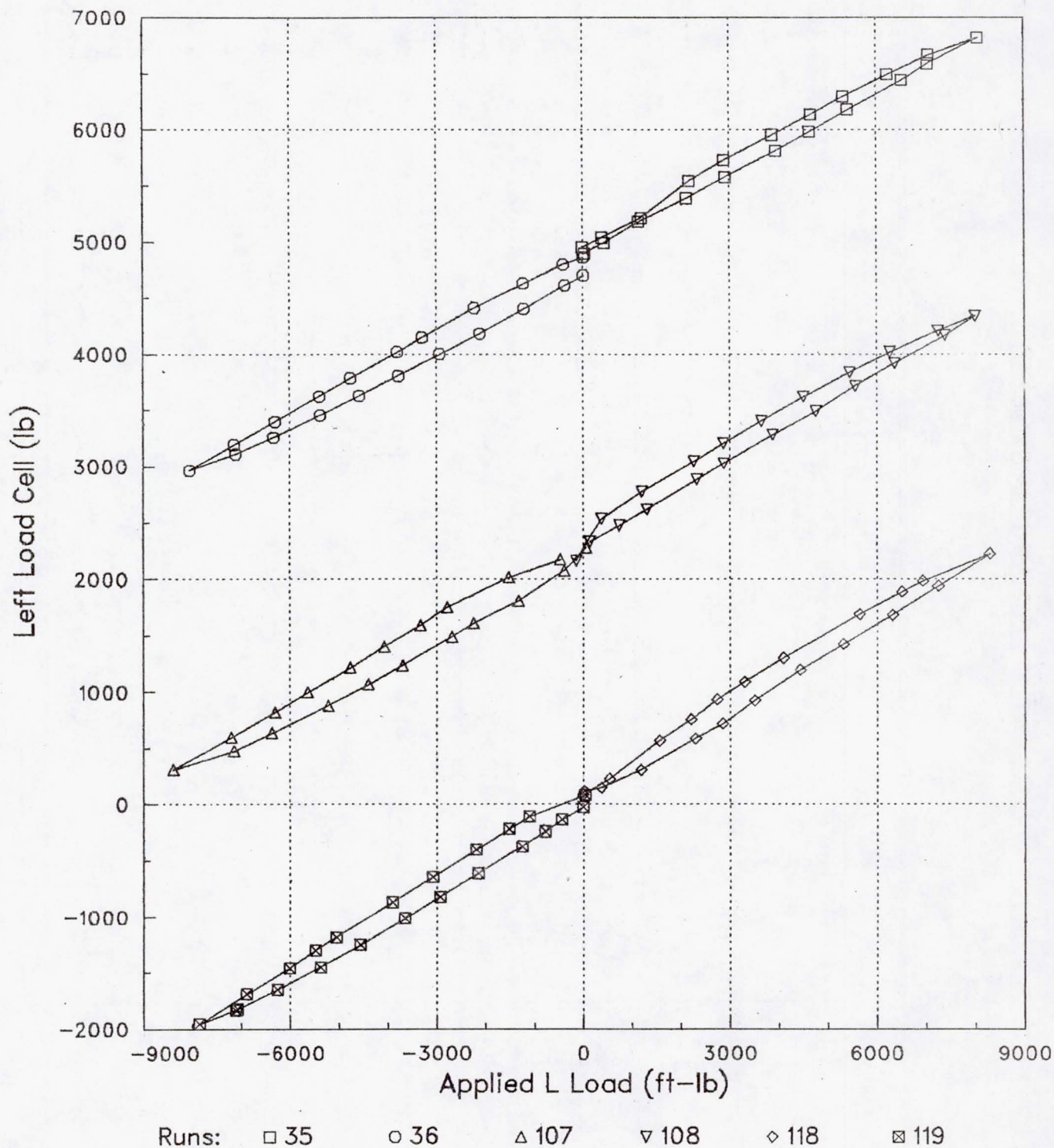
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

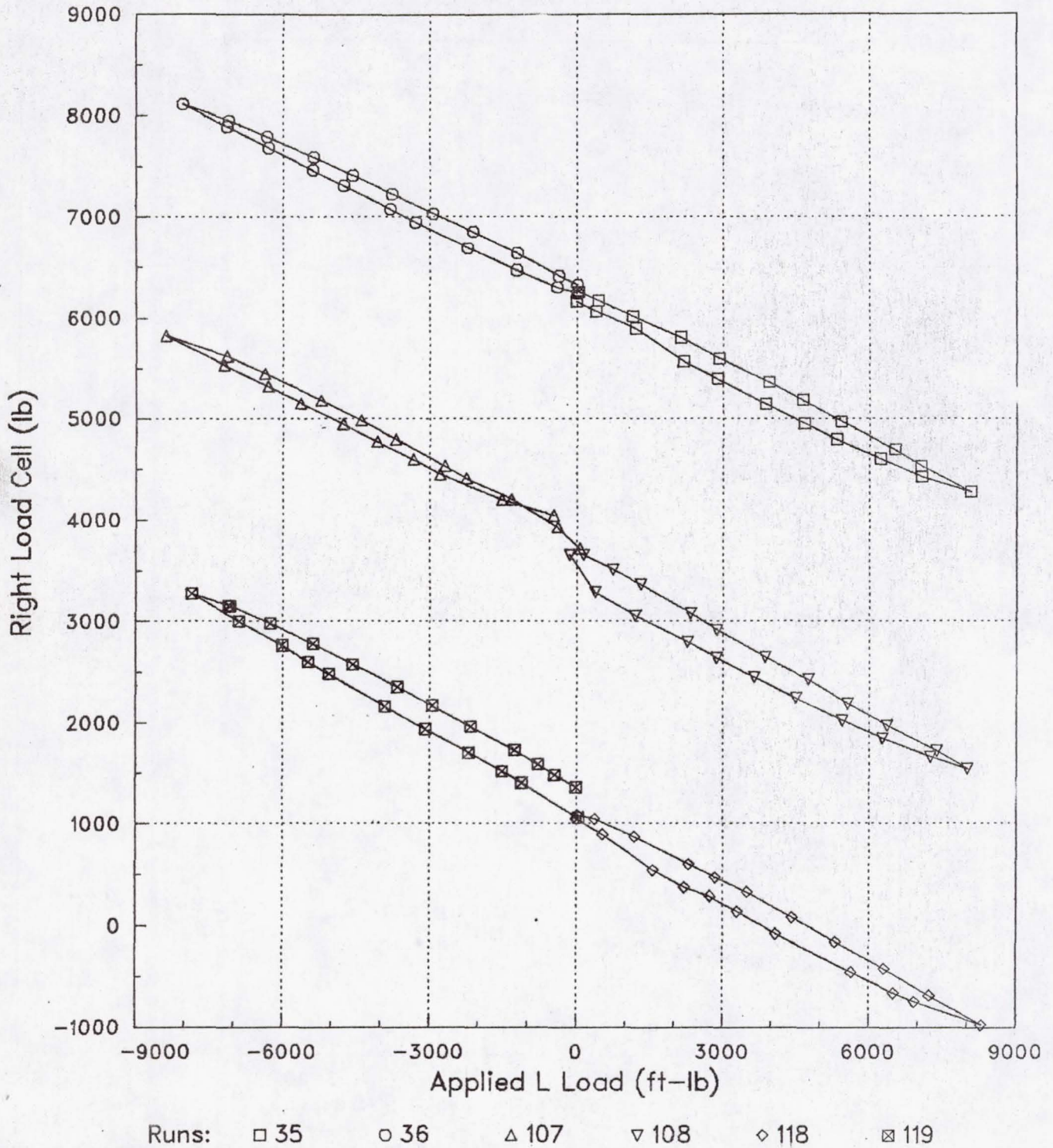
Applied L Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied L Load

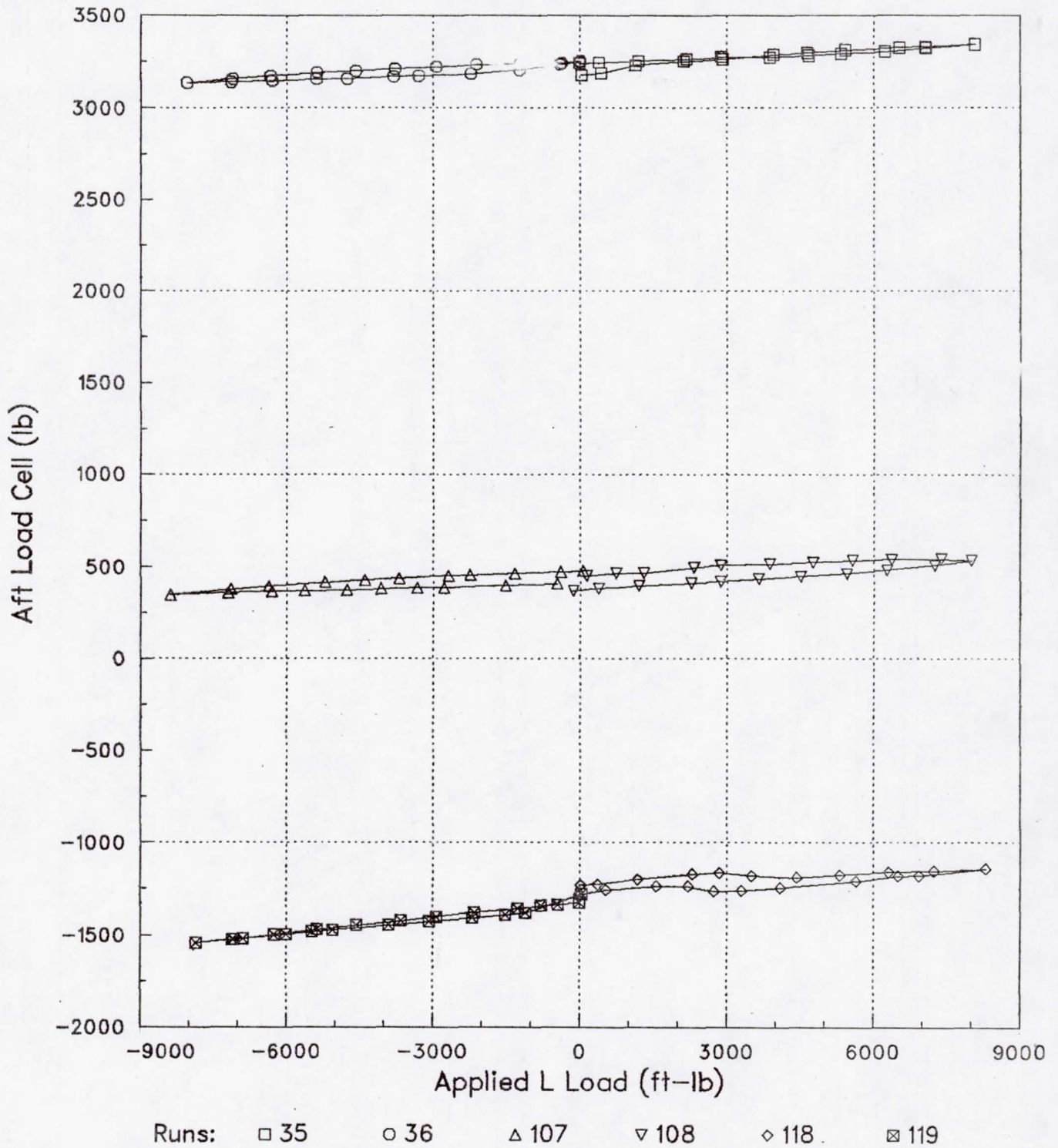
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied L Load

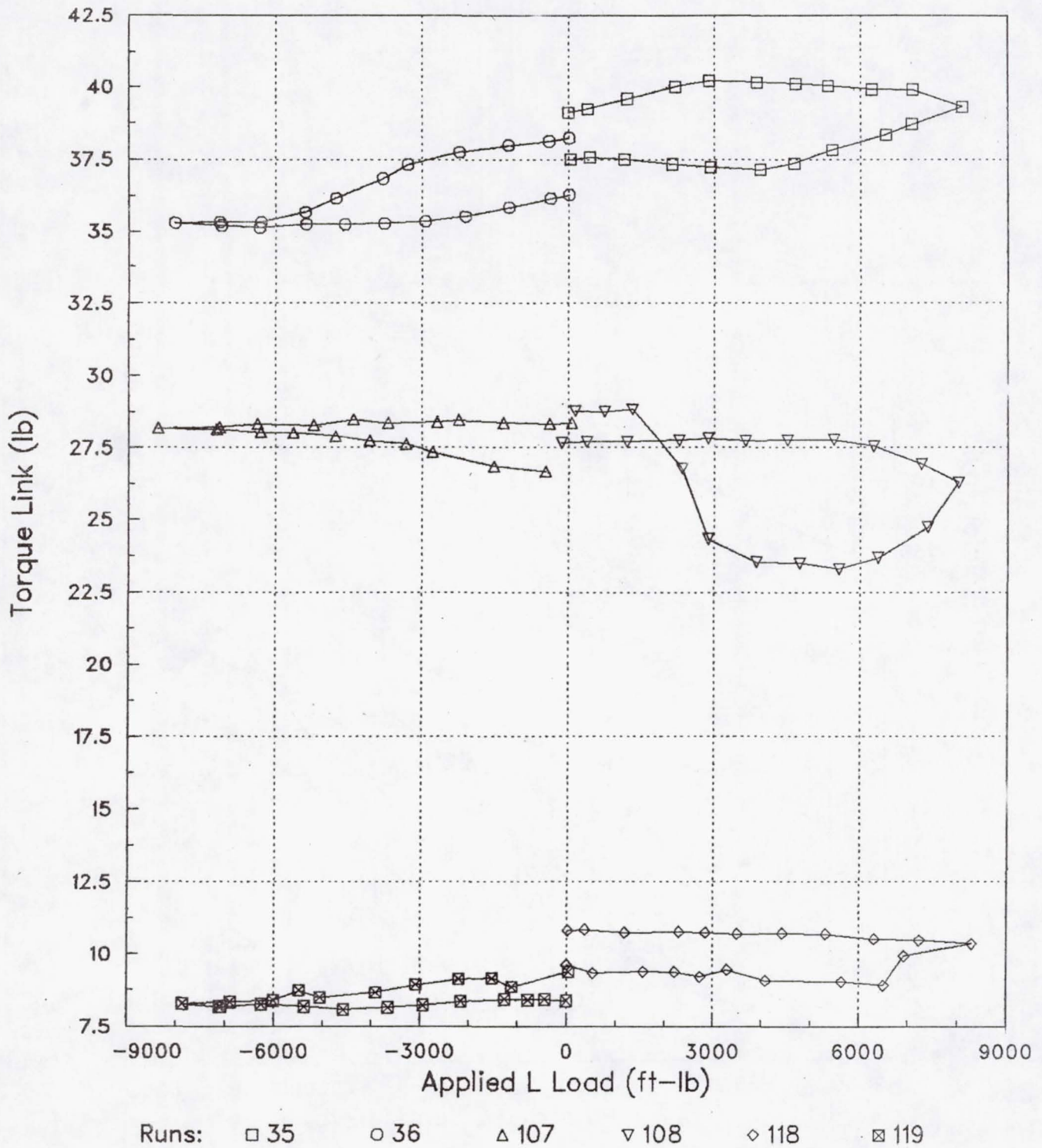
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

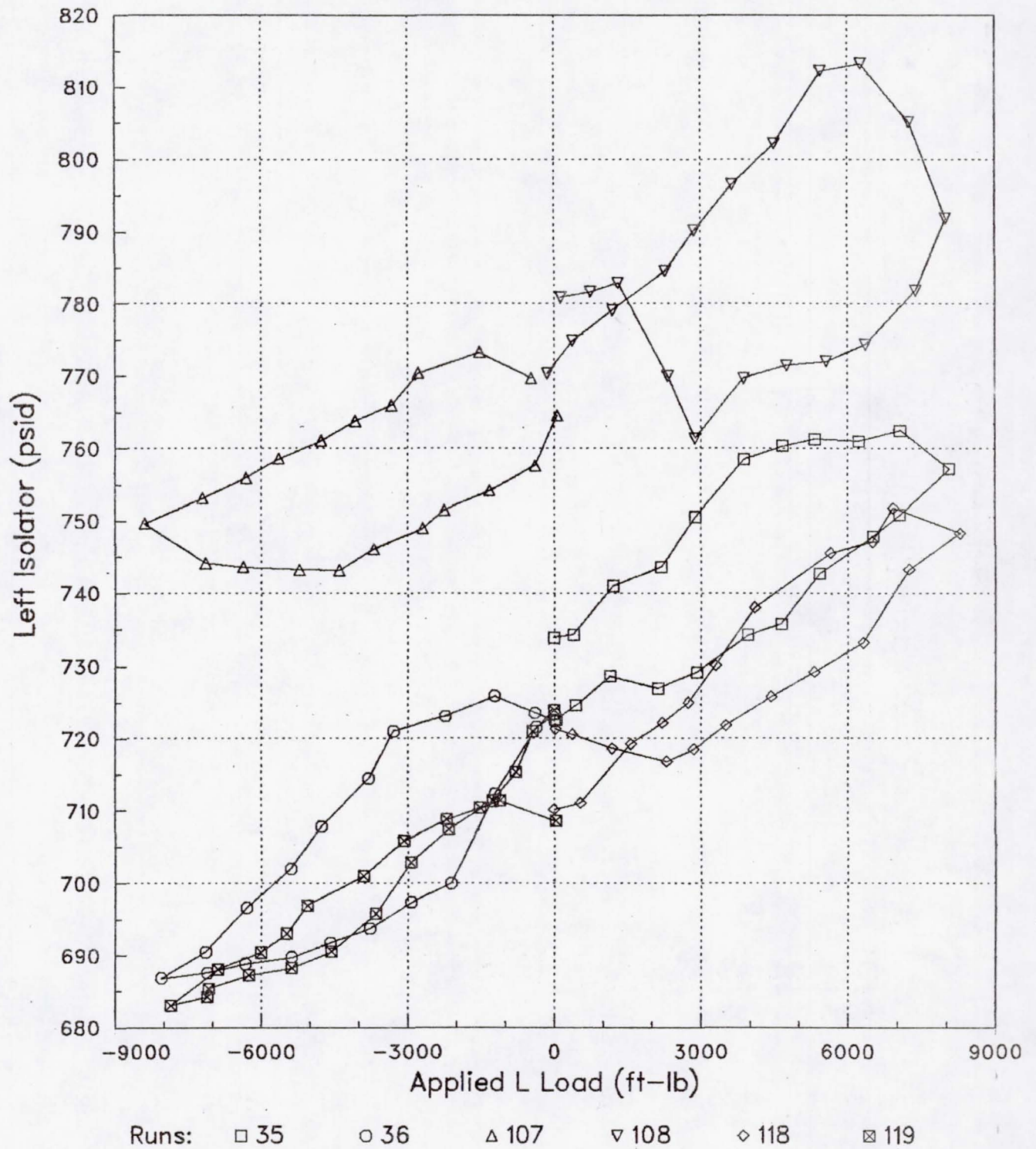
Applied L Load

Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

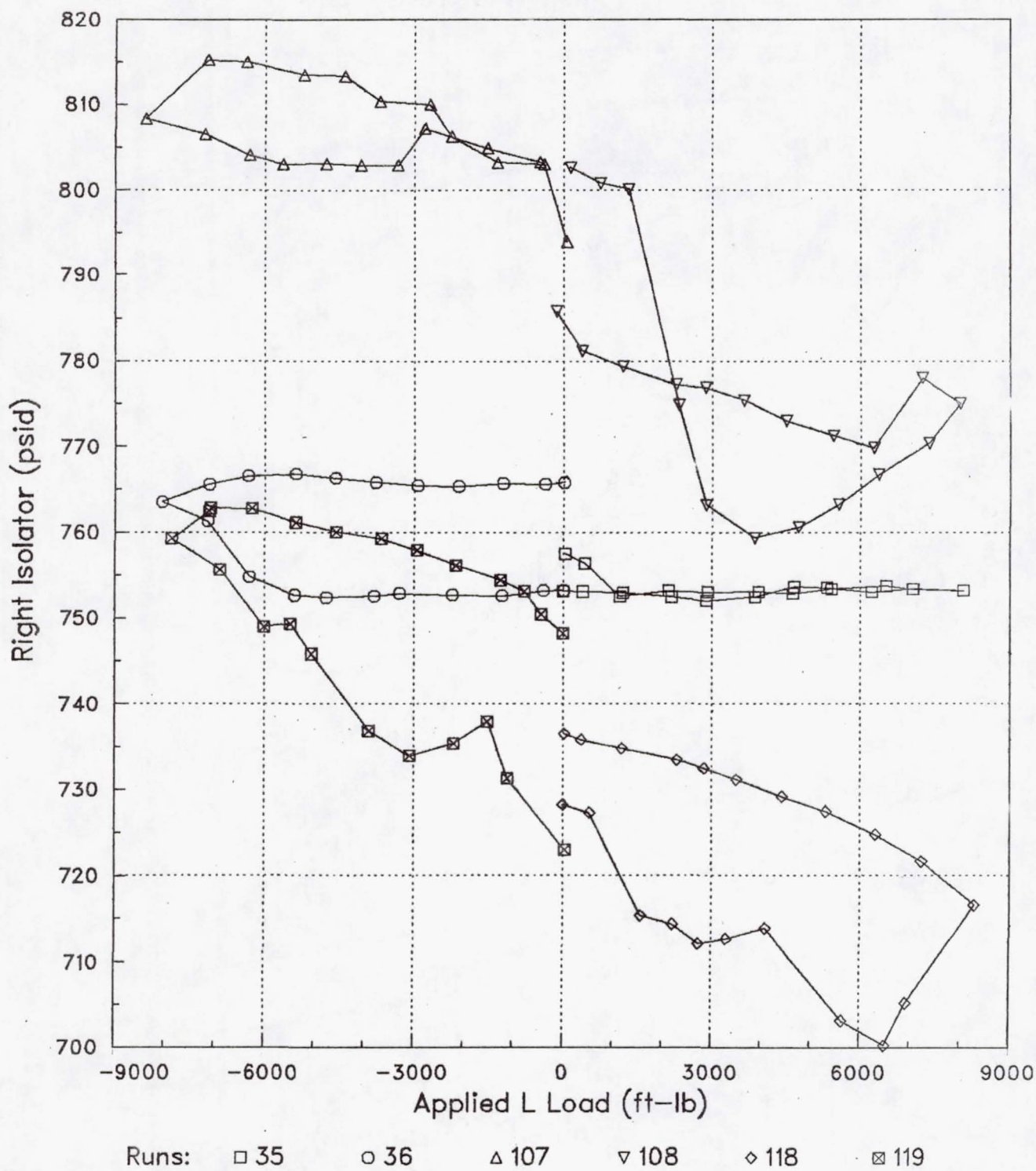
Applied L Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied L Load

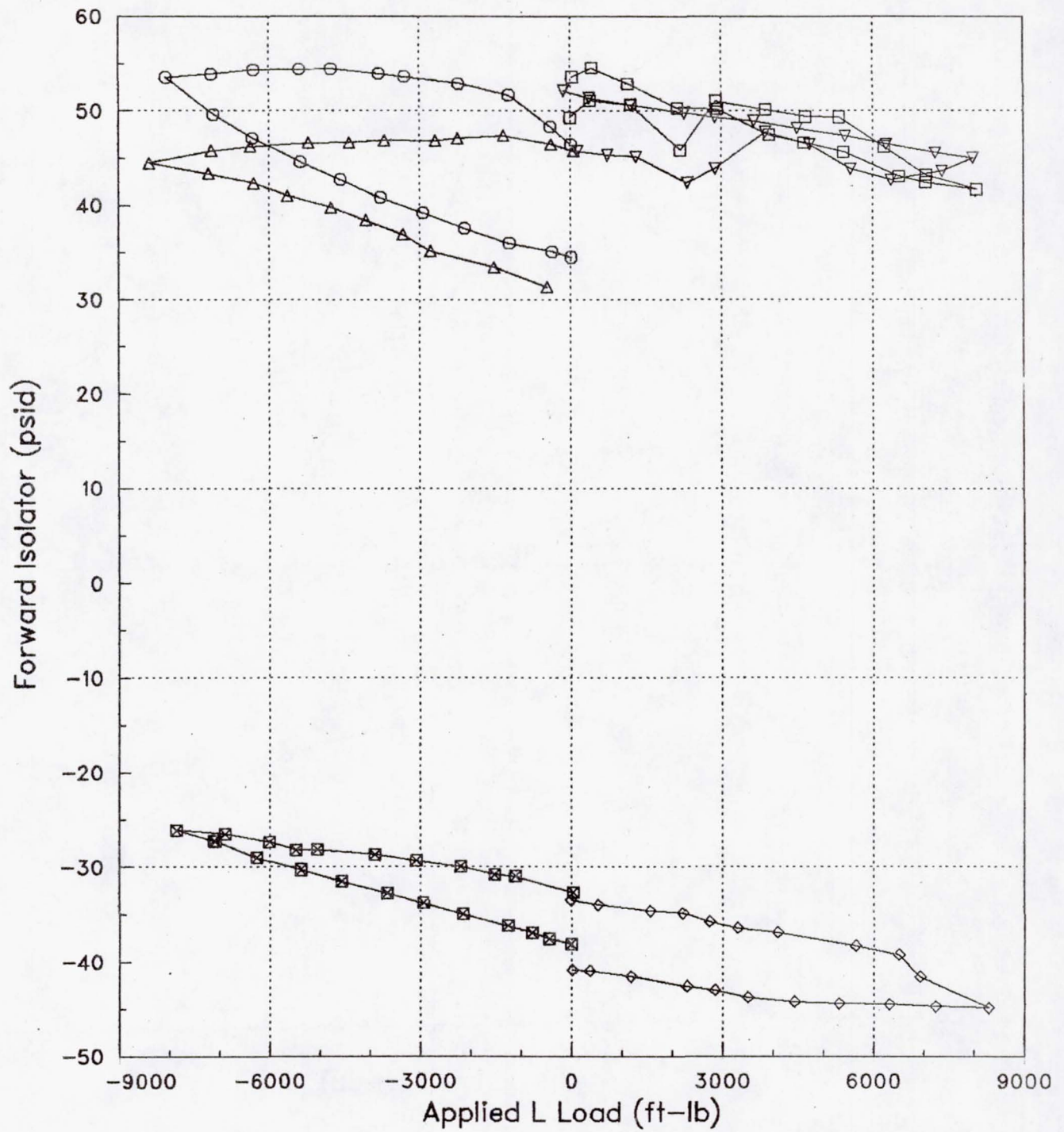
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied L Load

Constant Loads: Z, 85% N

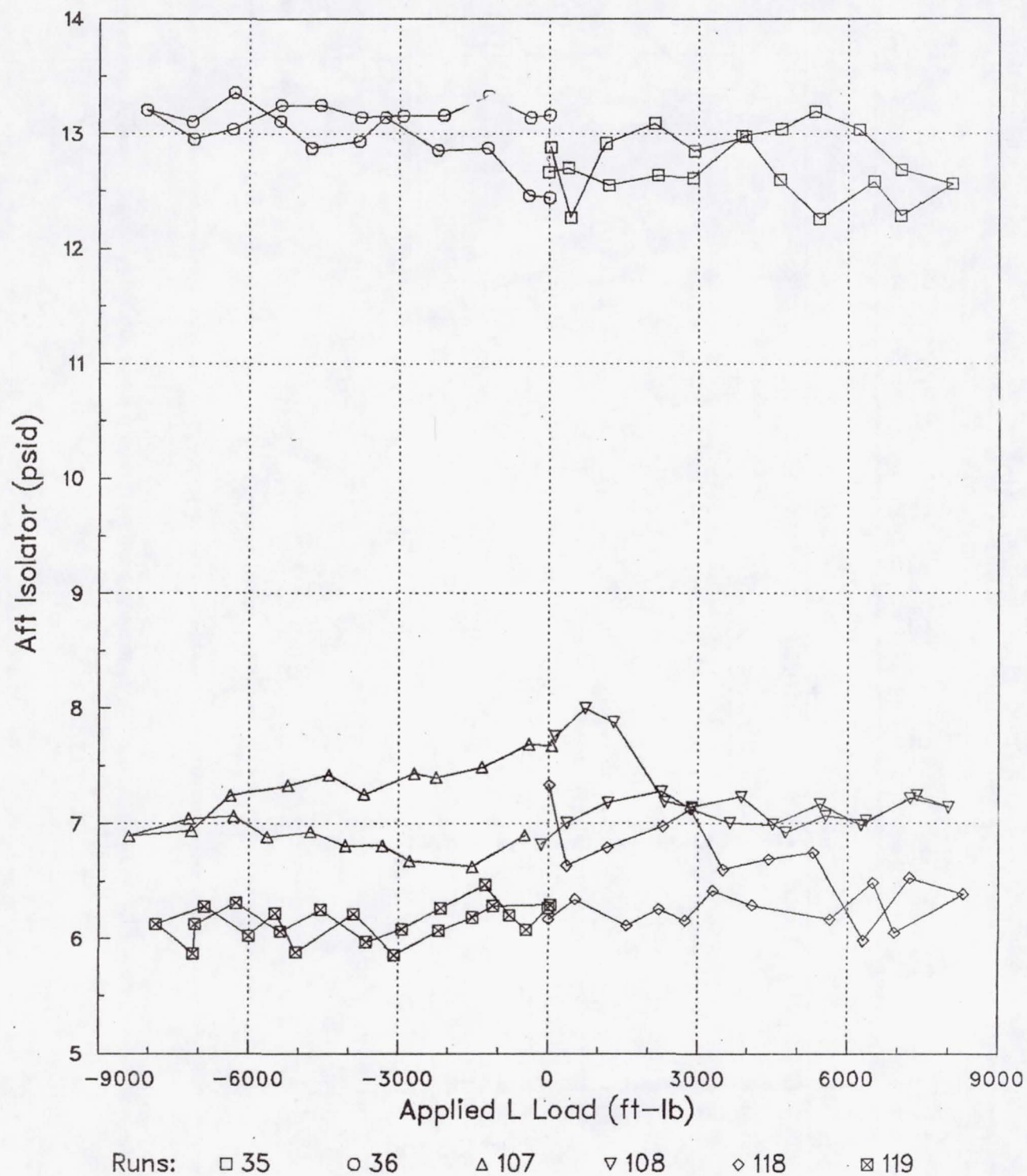


Runs: □ 35 ○ 36 △ 107 ▽ 108 ◇ 118 ⊠ 119

RSRA 741 1983 ROTOR CALIBRATION

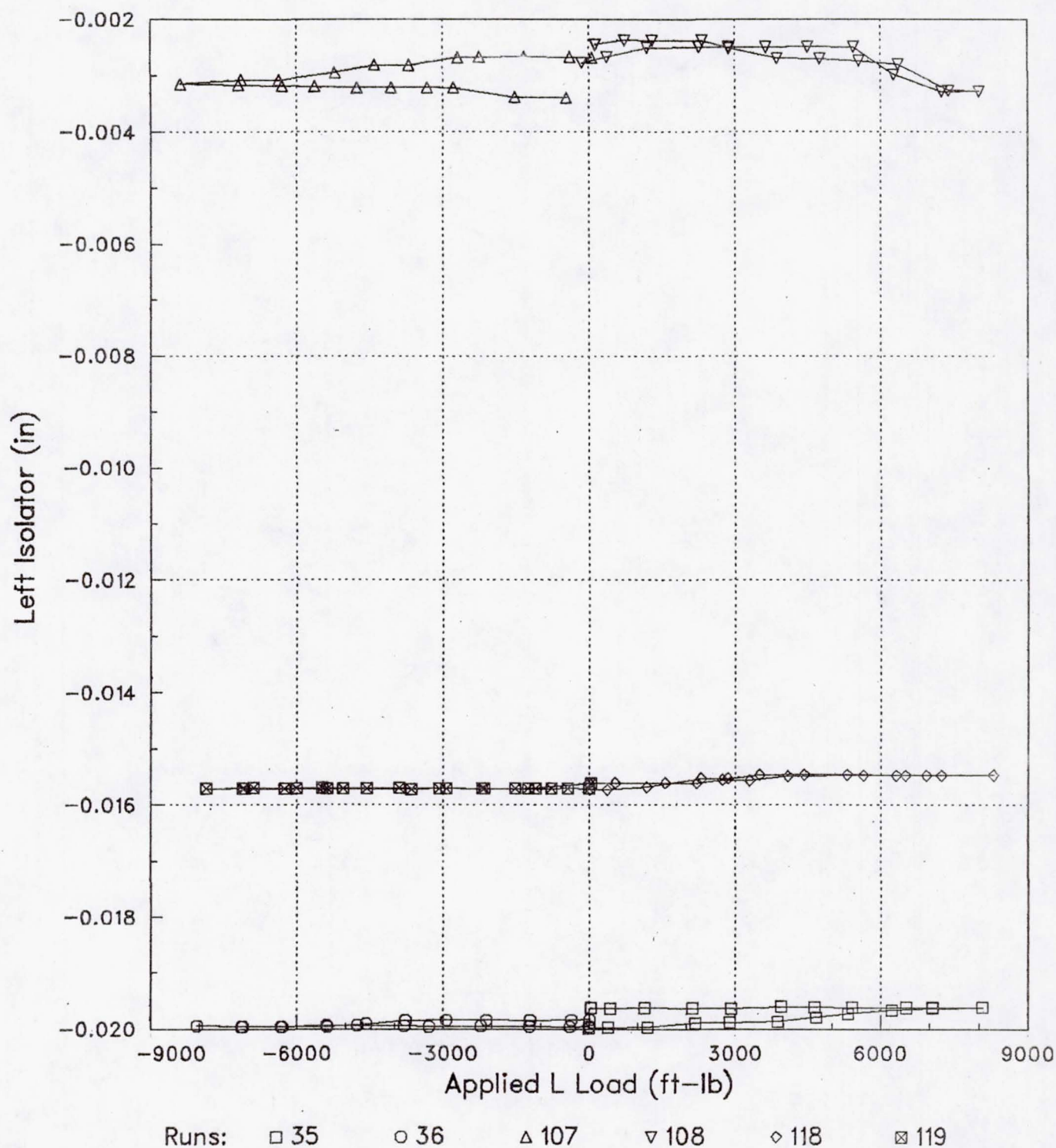
Applied L Load

Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

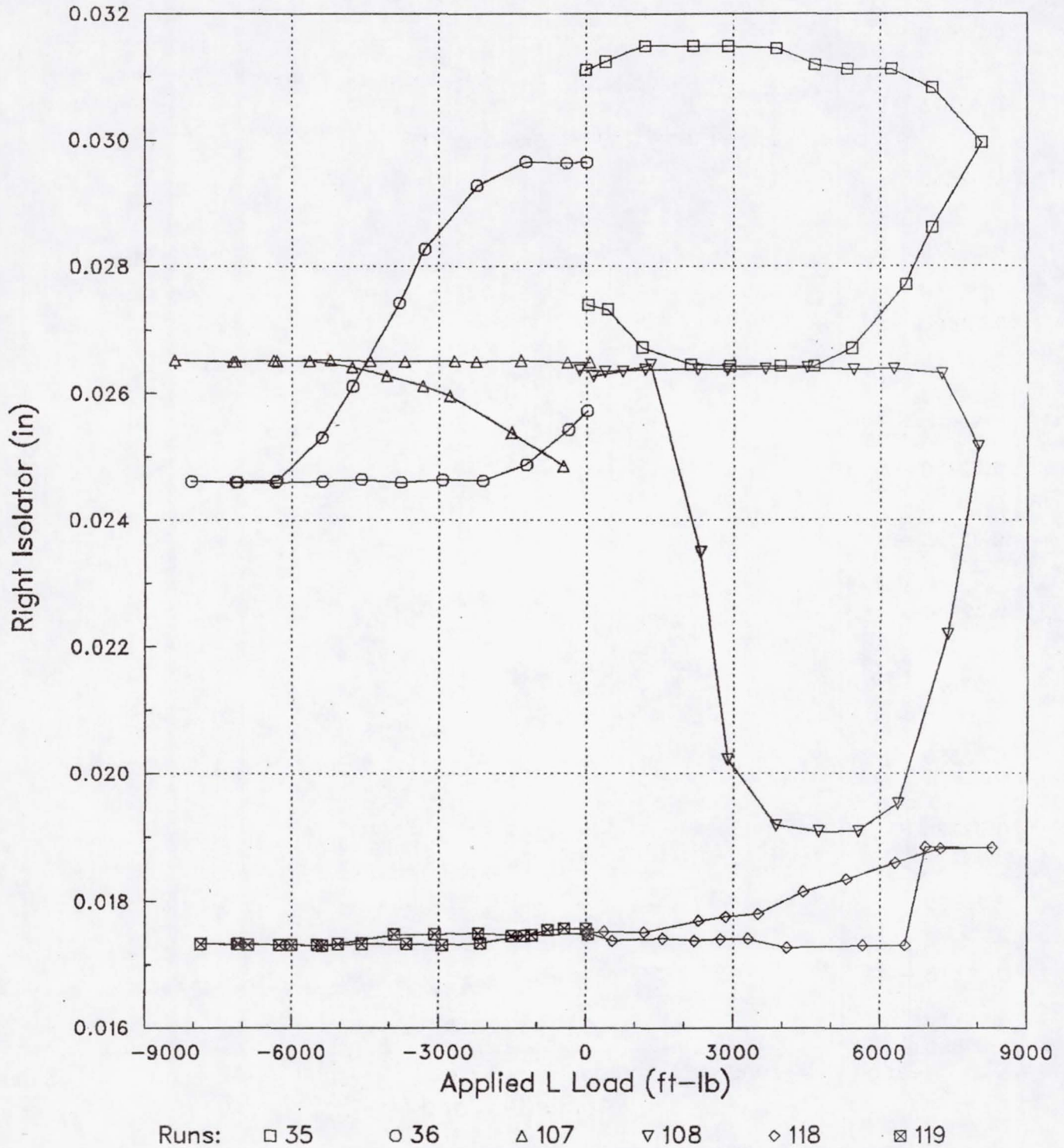
Applied L Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

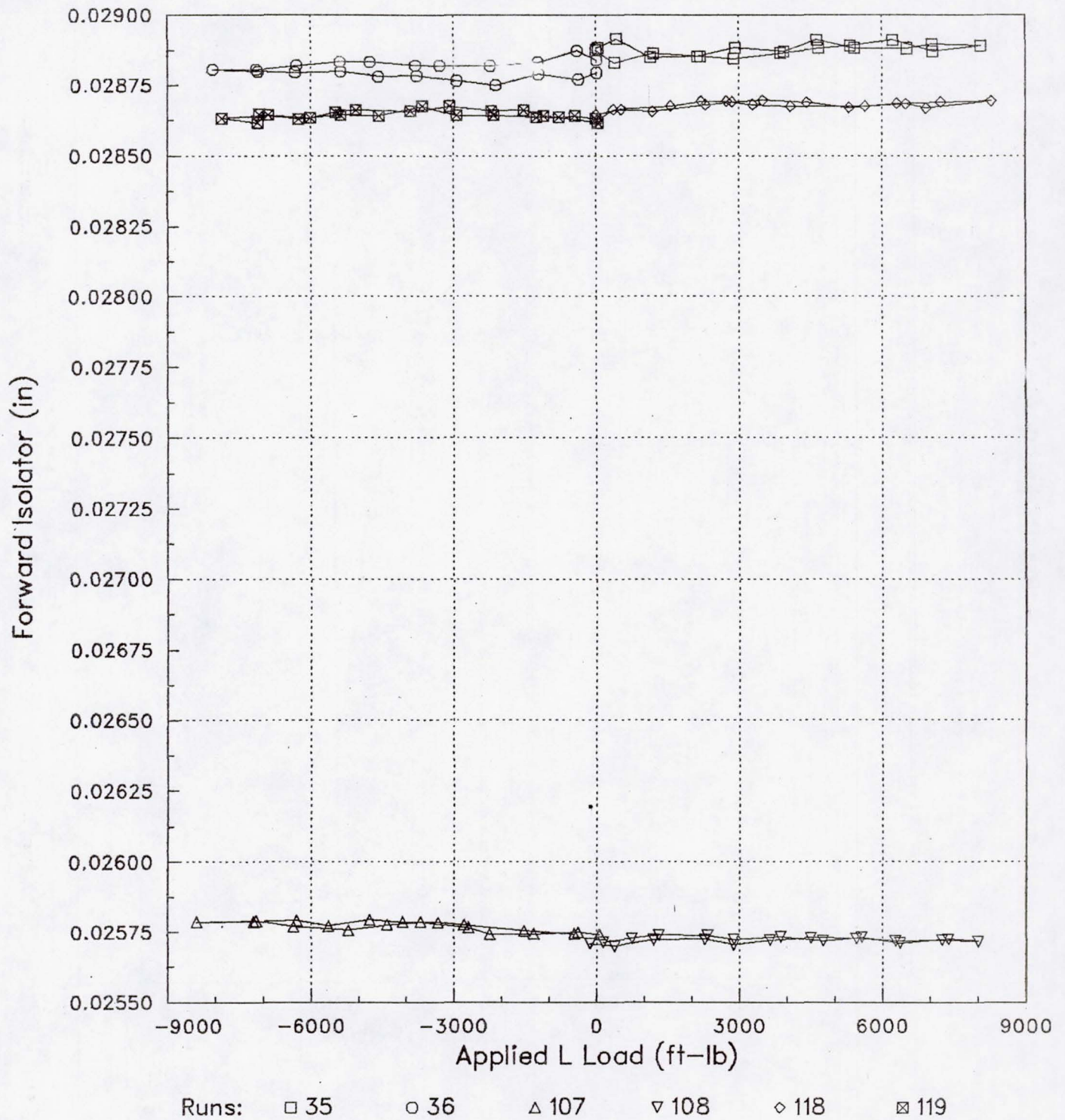
Applied L Load

Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

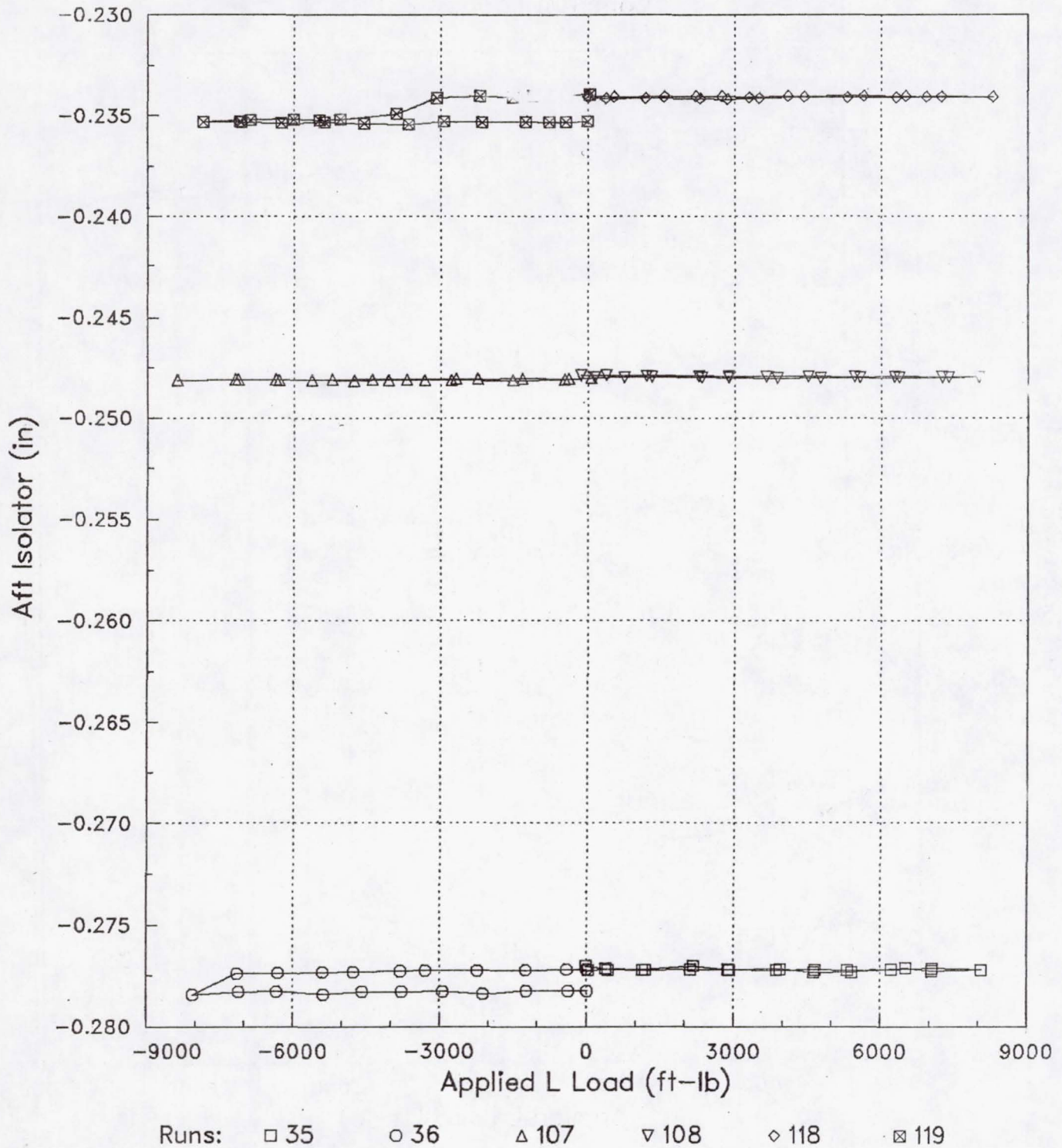
Applied L Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

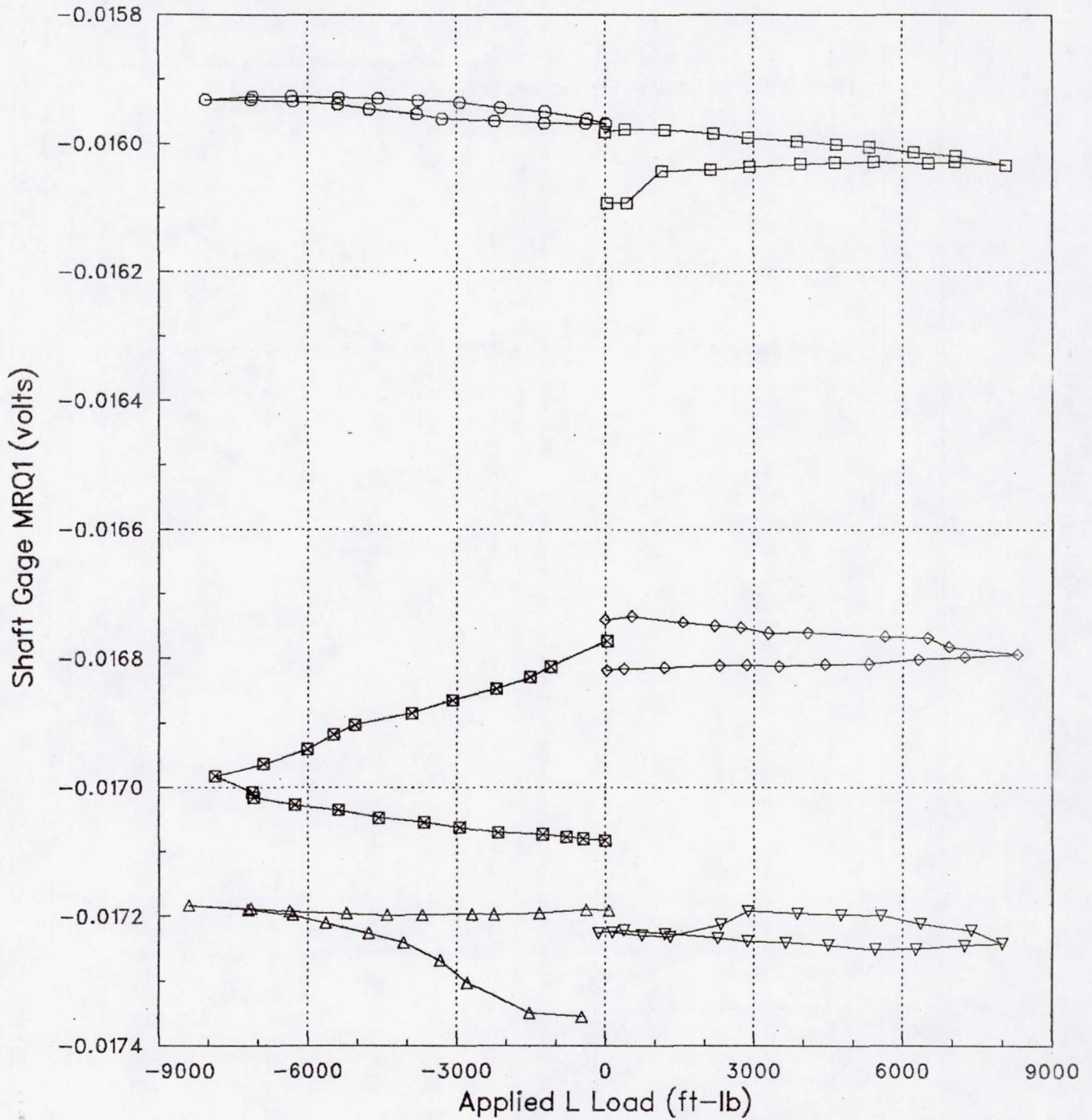
Applied L Load

Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: Z, 85% N

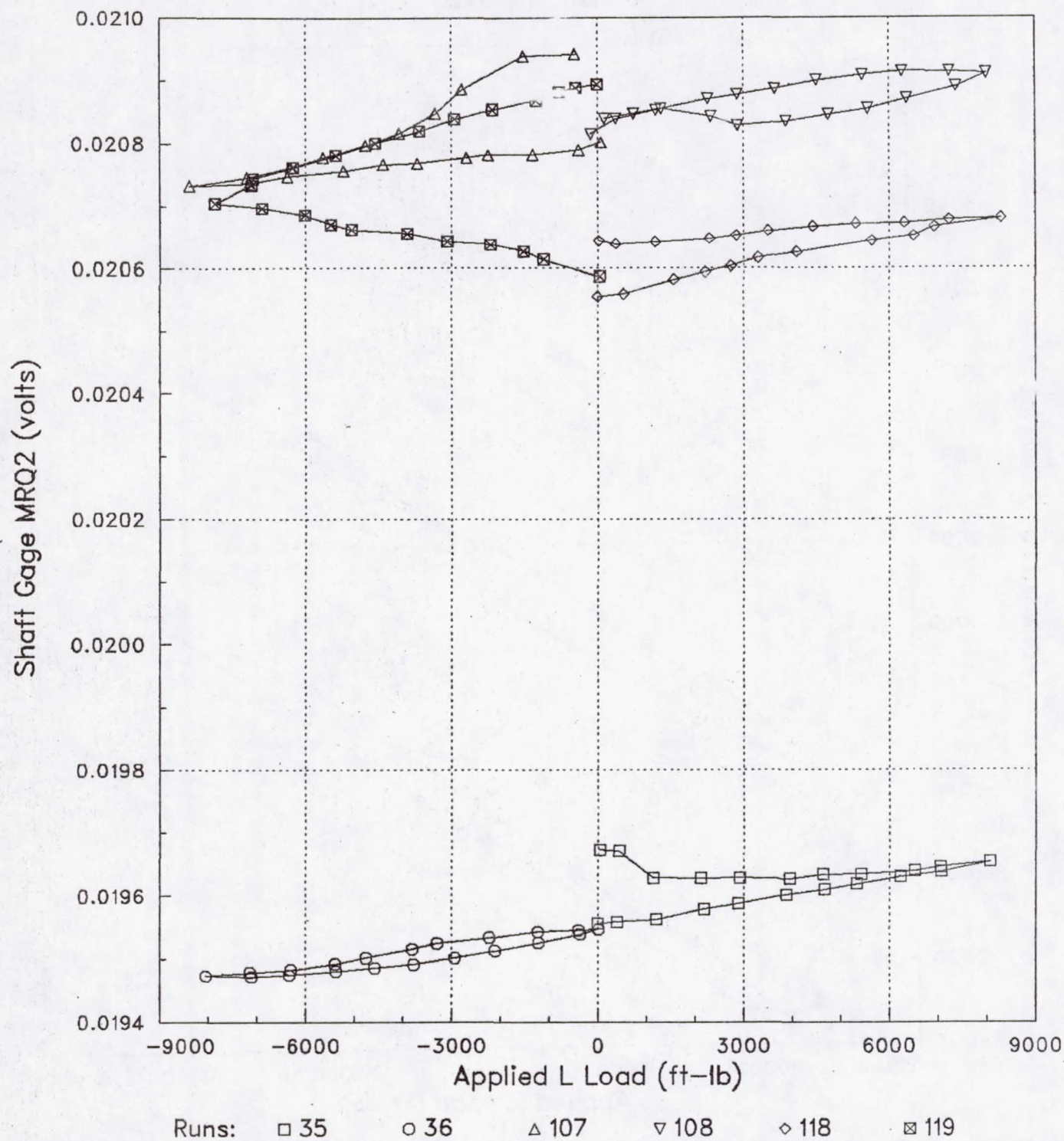


Runs: □ 35 ○ 36 △ 107 ▽ 108 ◇ 118 ⊠ 119

RSRA 741 1983 ROTOR CALIBRATION

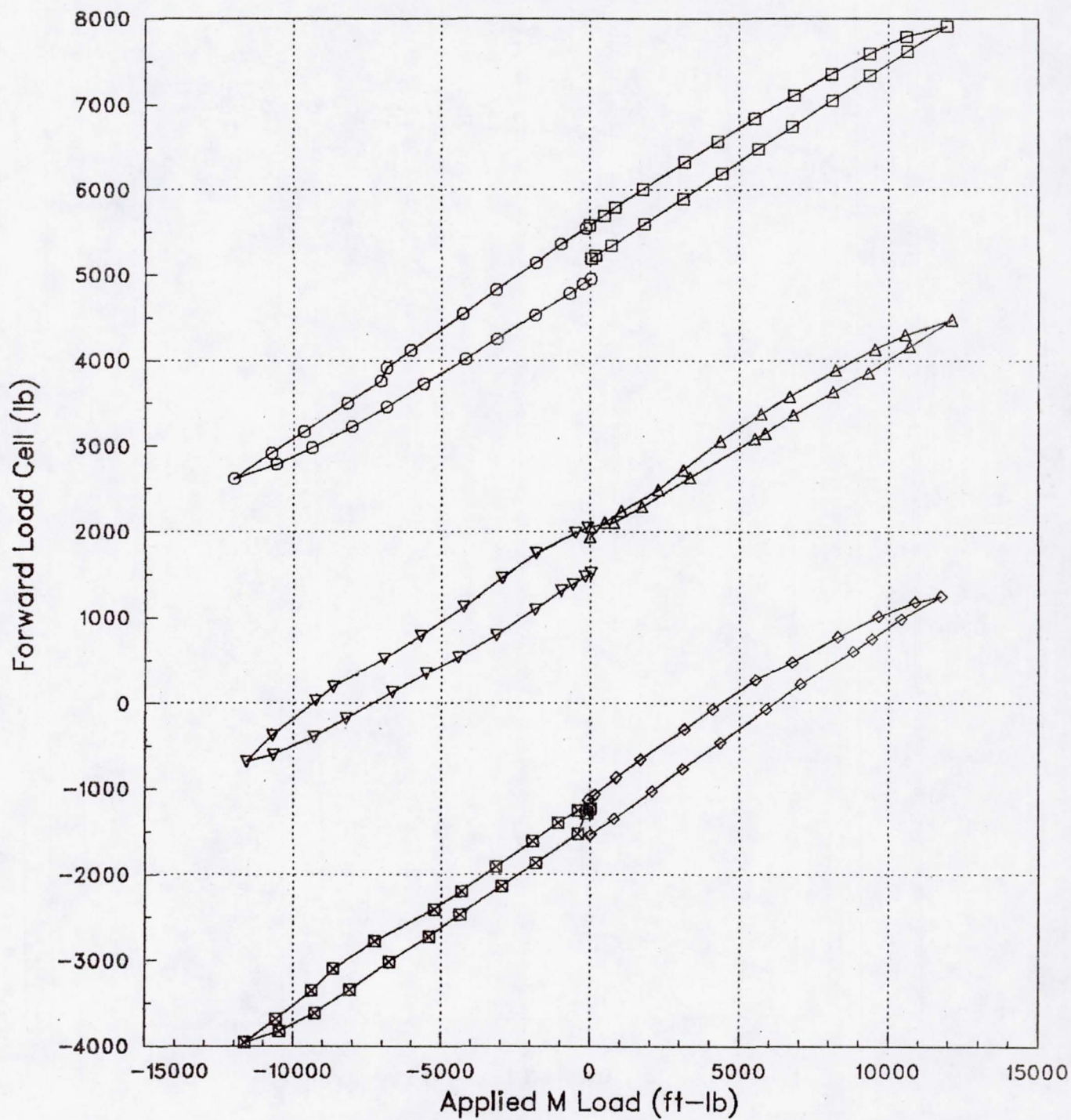
Applied L Load

Constant Loads: Z, 85% N



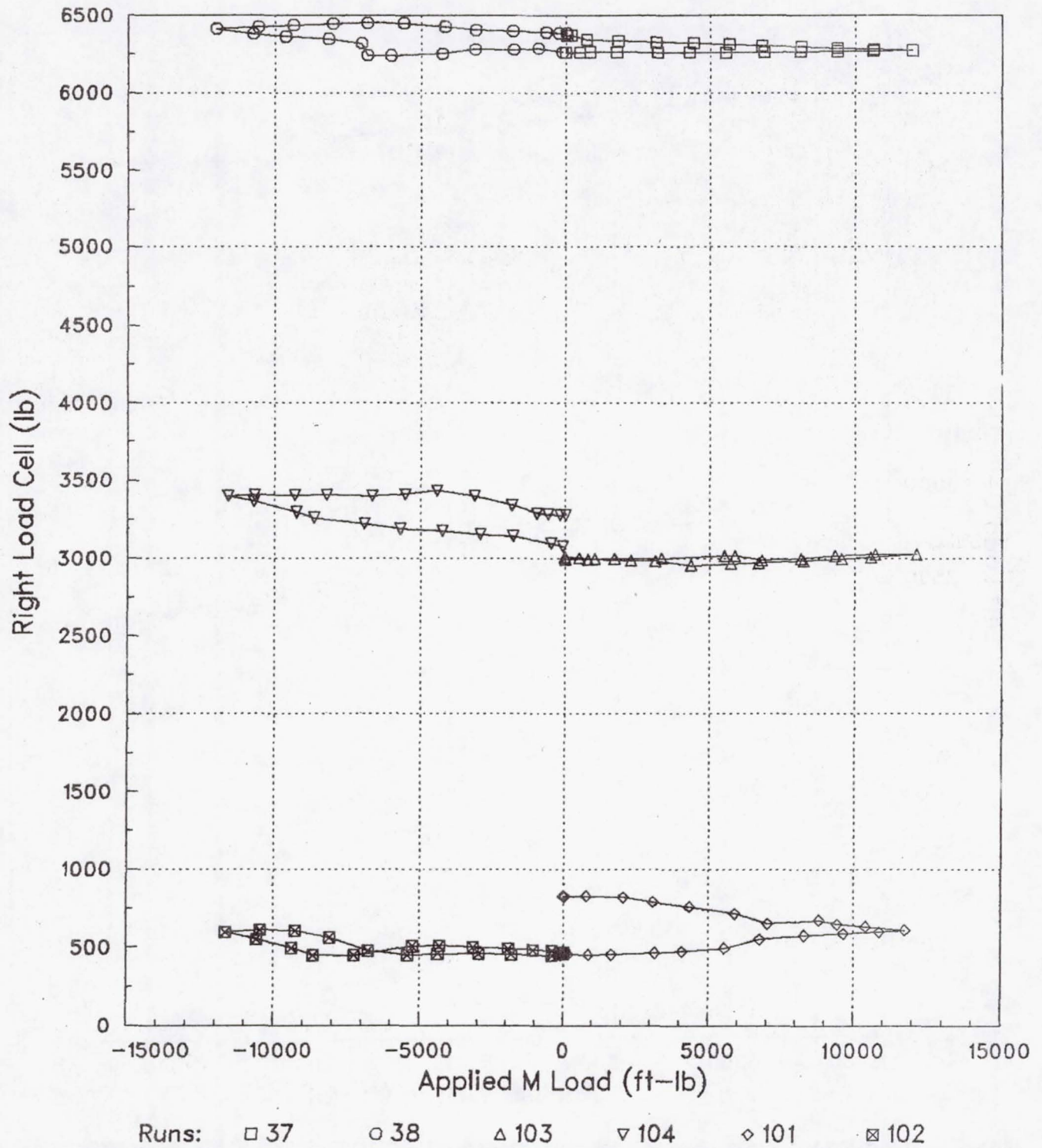
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: Z, 85% N



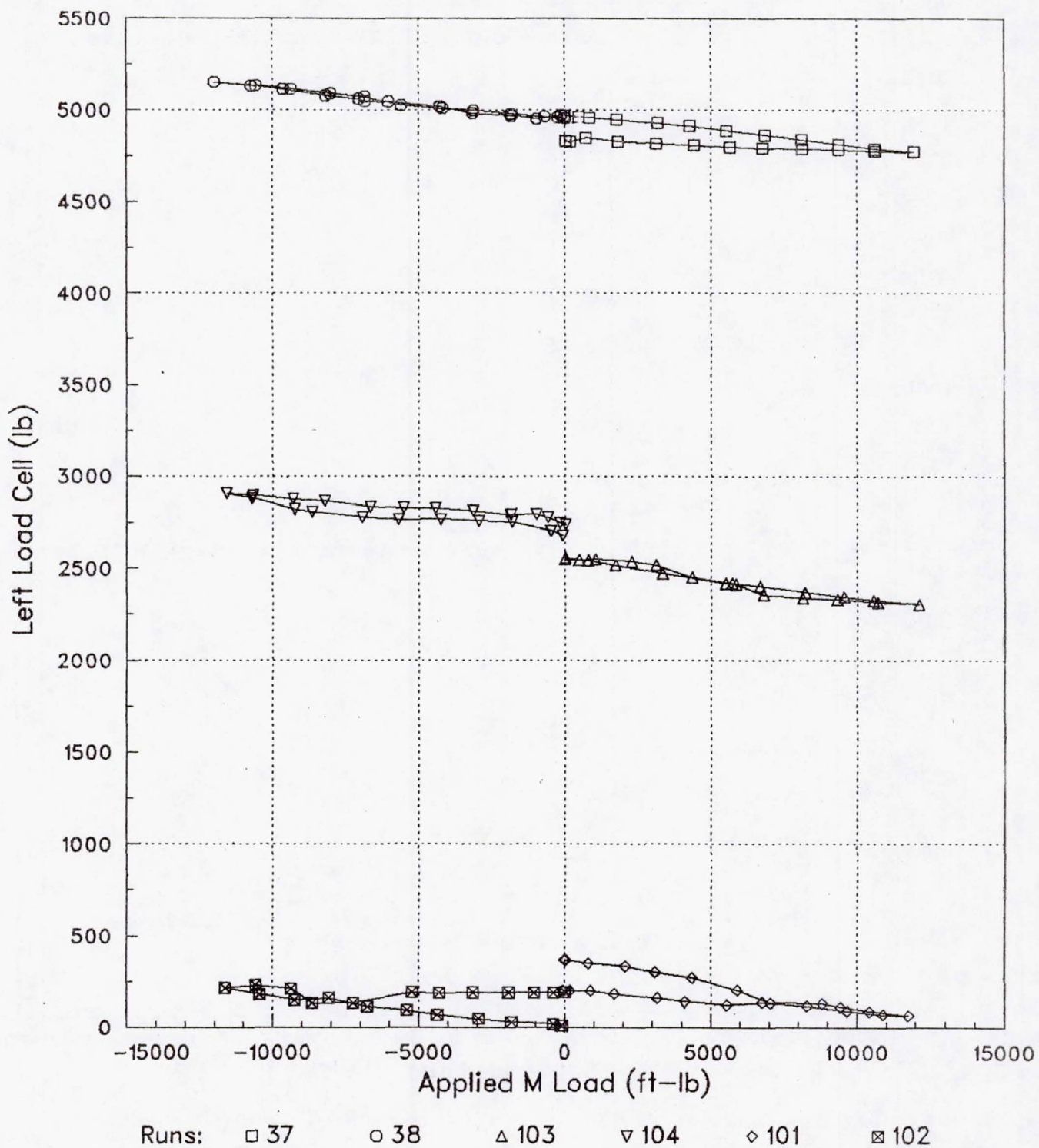
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

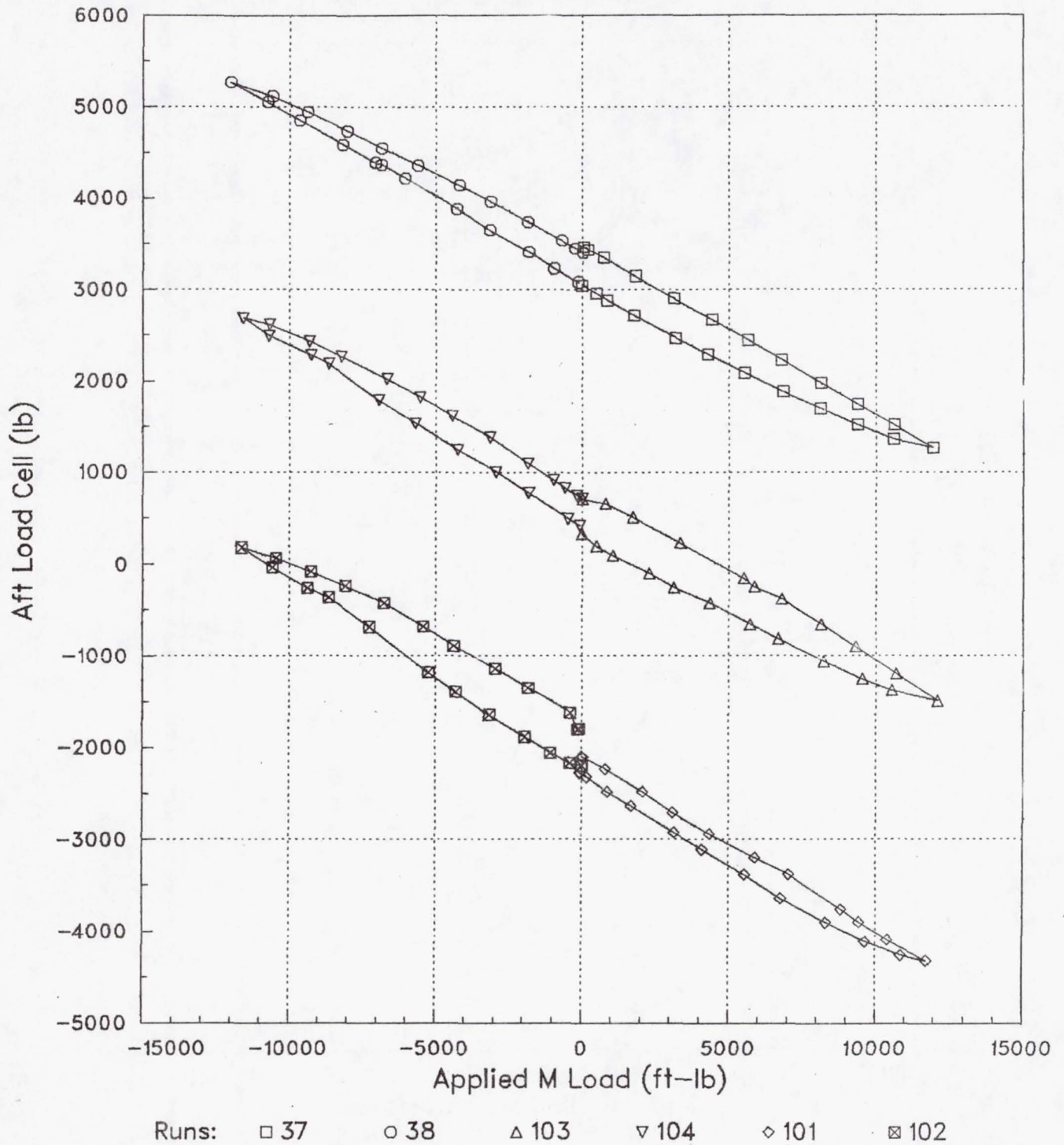
Applied M Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

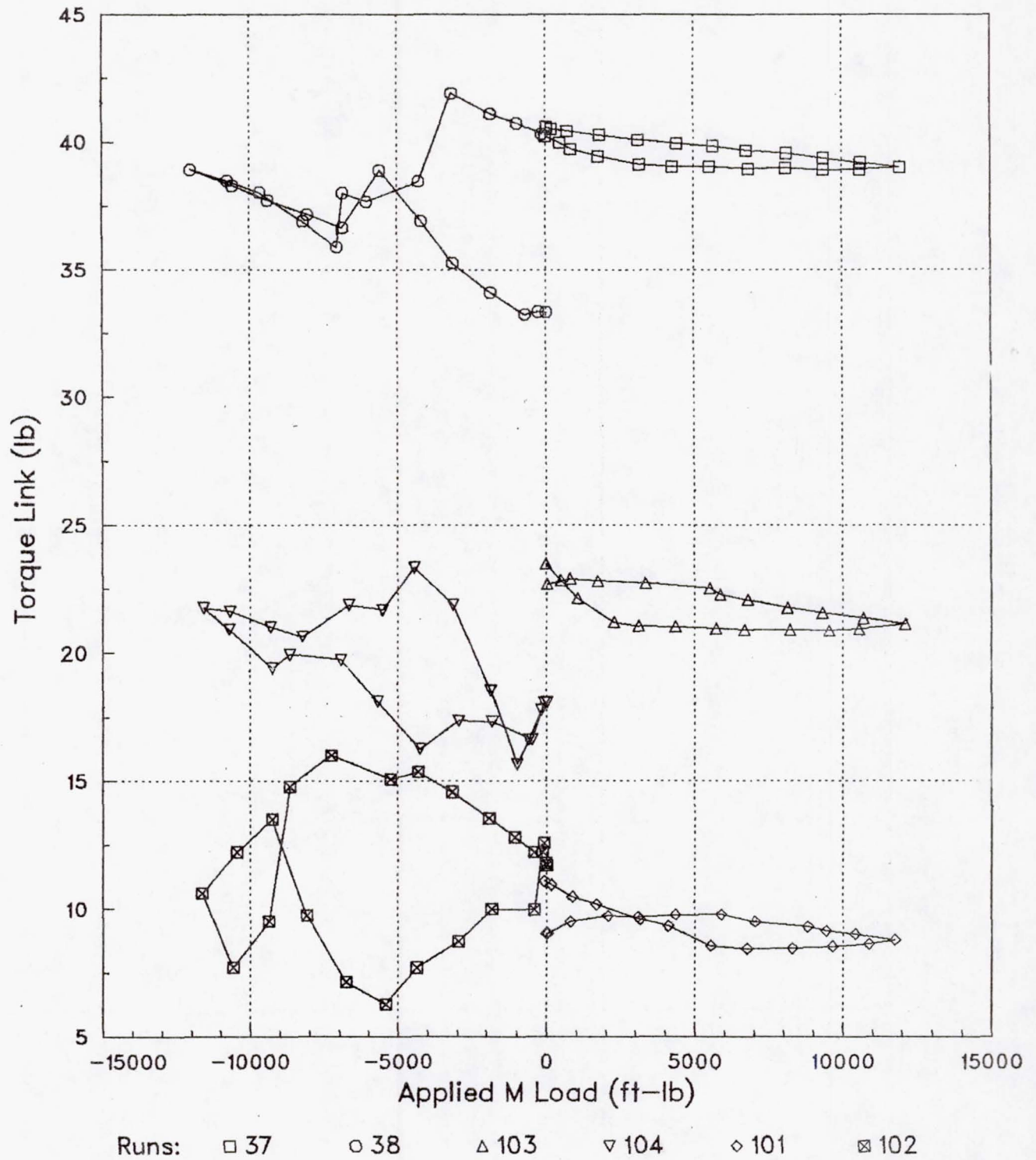
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

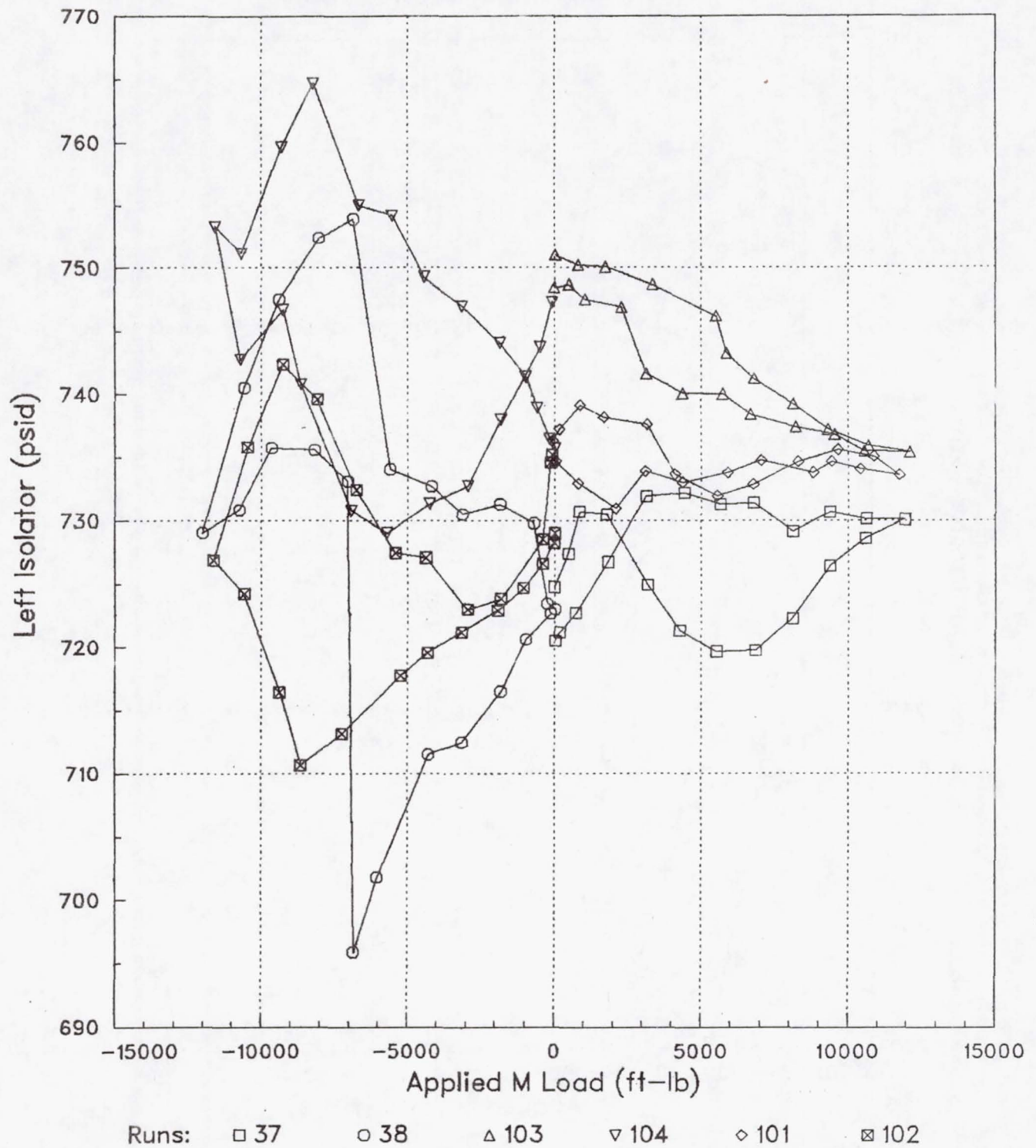
Applied M Load

Constant Loads: Z, 85% N



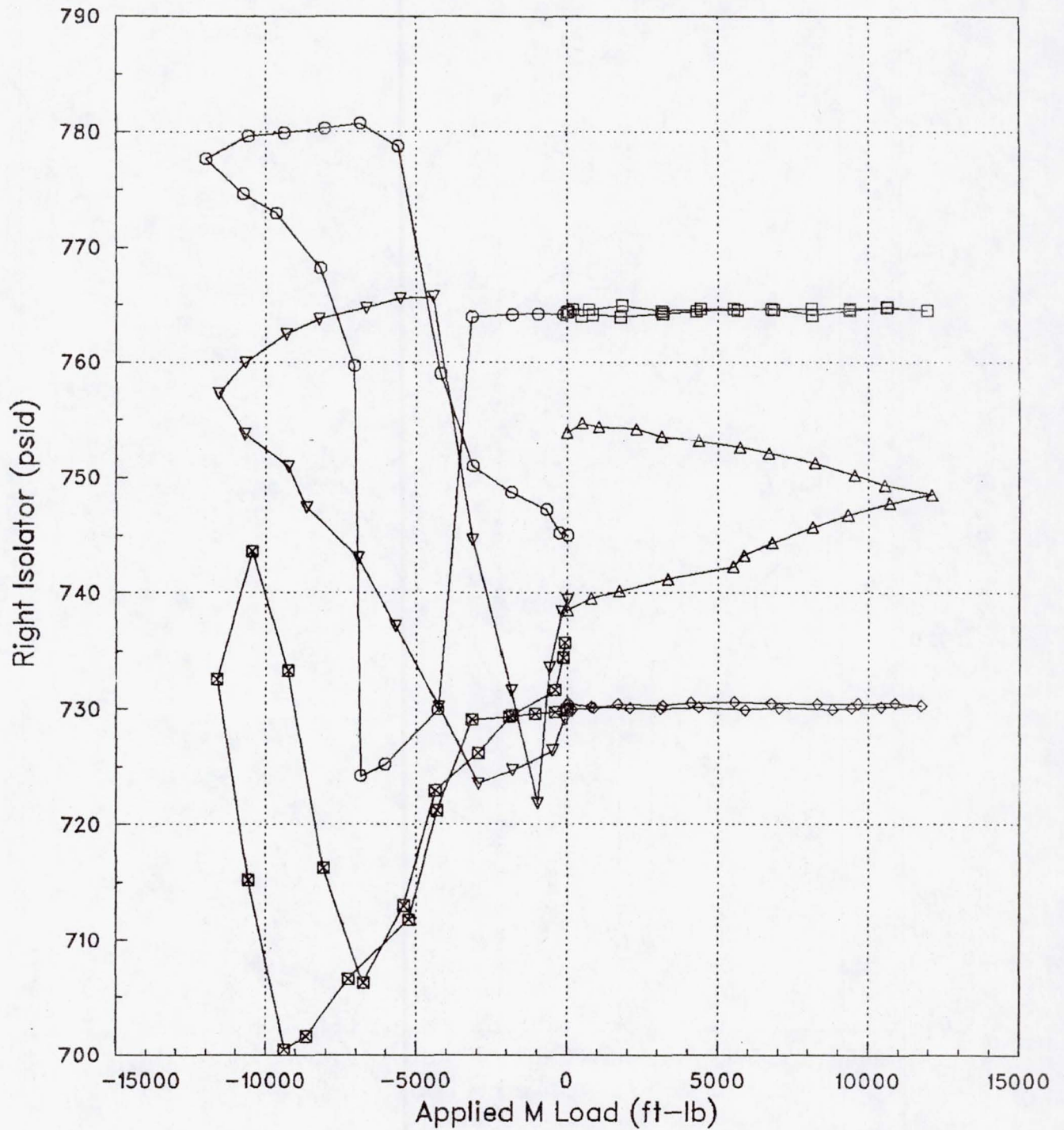
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load
Constant Loads: Z, 85% N

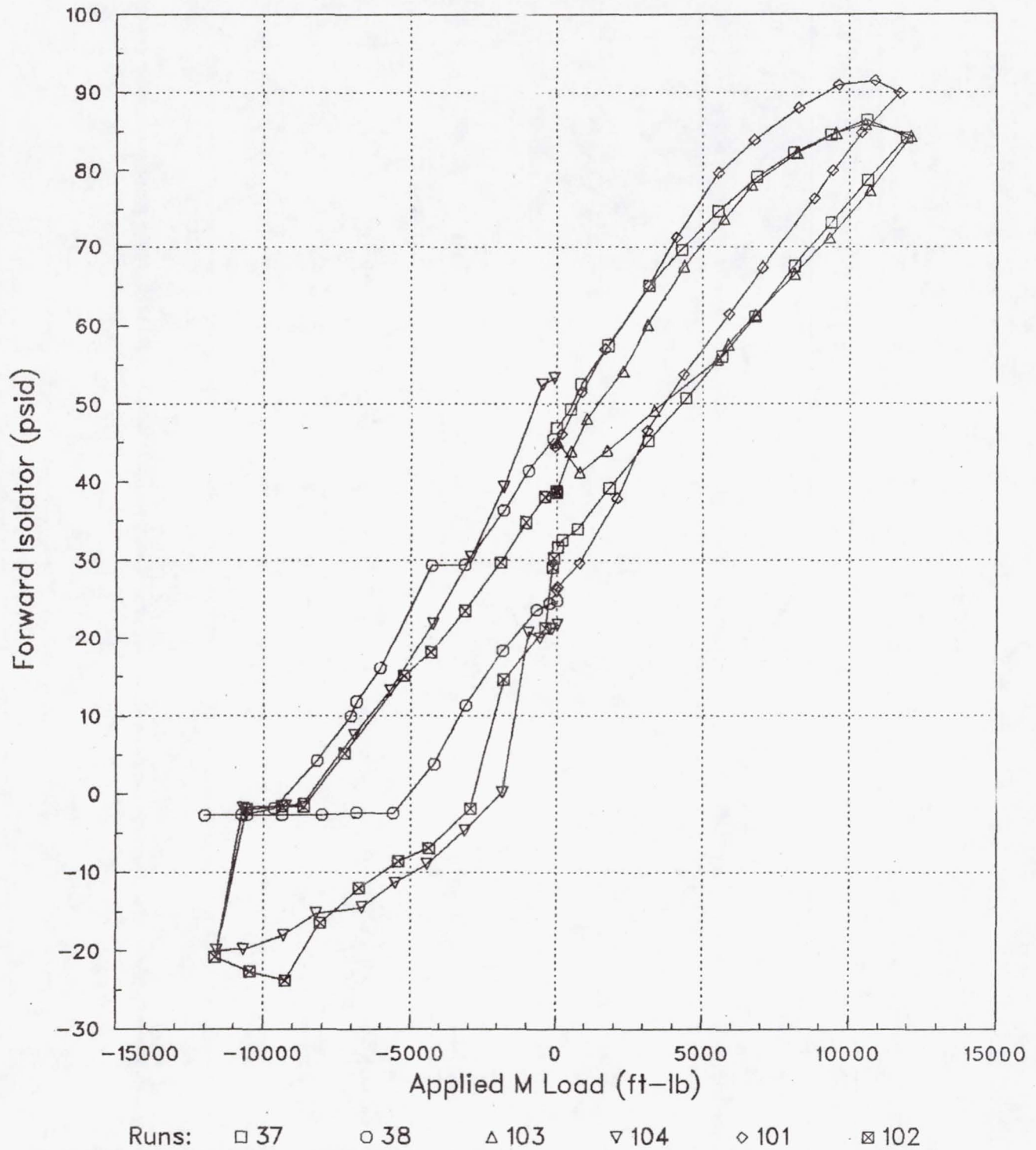


Runs: □ 37 ○ 38 △ 103 ▽ 104 ◇ 101 ⊠ 102

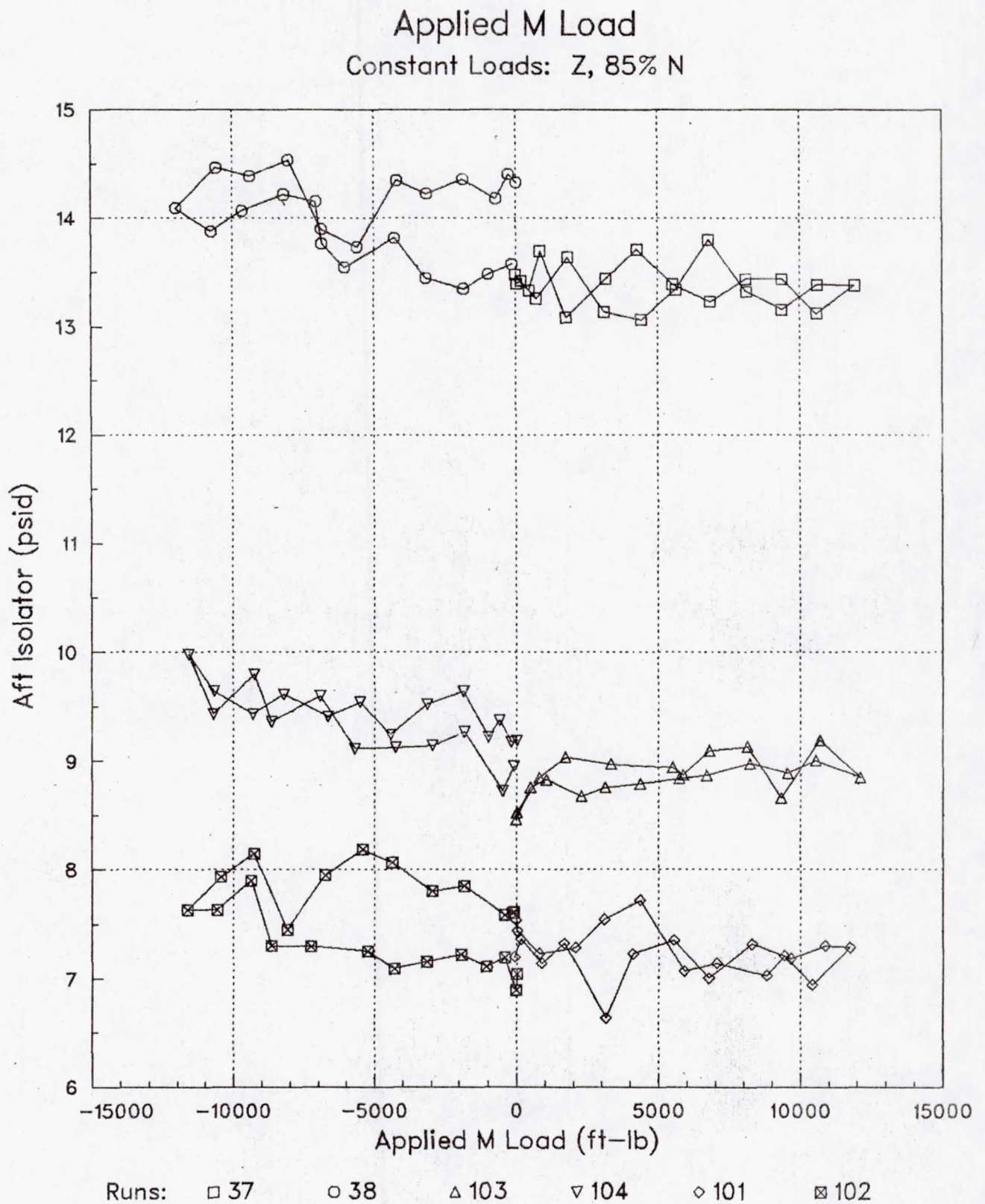
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

Constant Loads: Z, 85% N



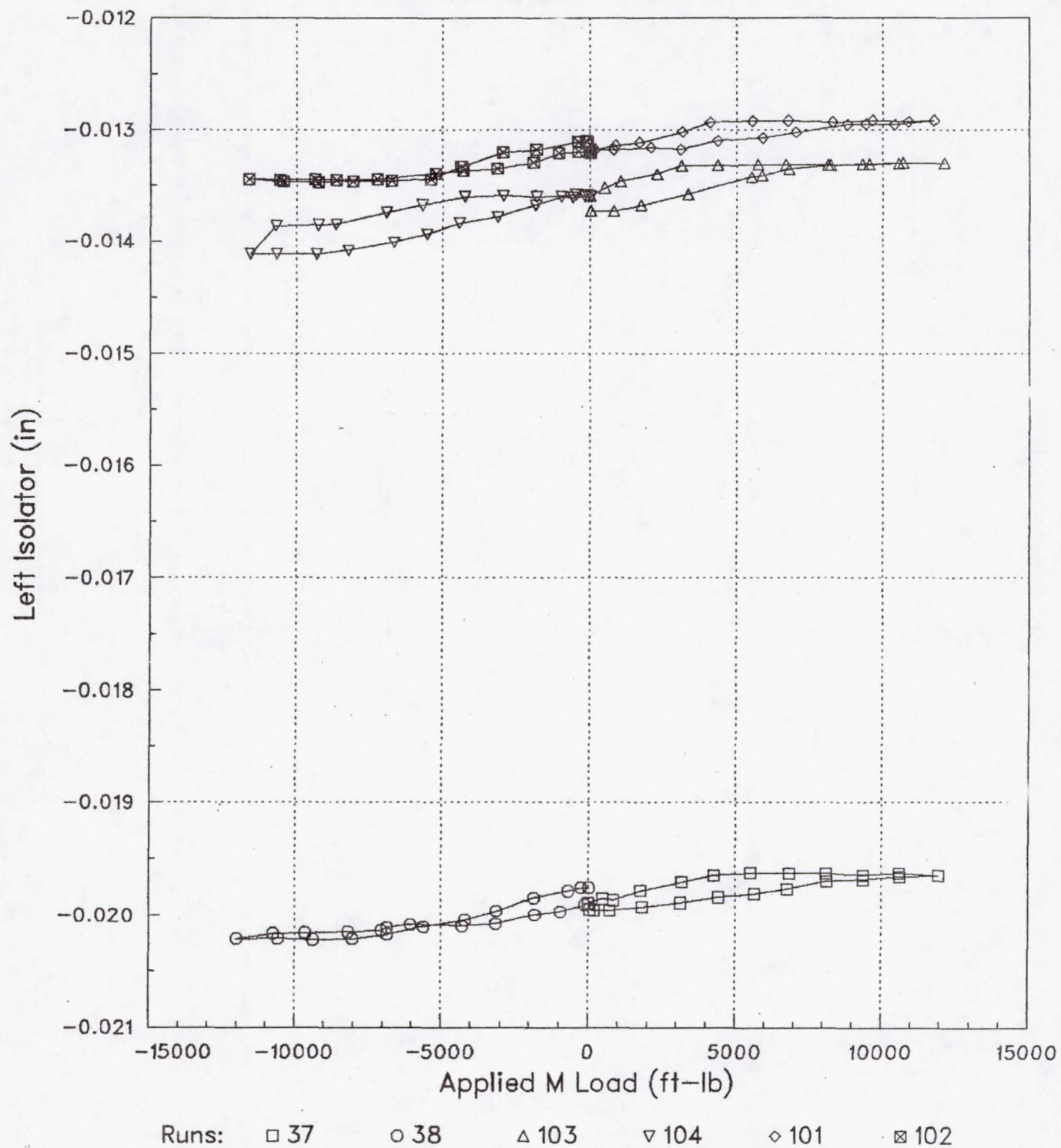
RSRA 741 1983 ROTOR CALIBRATION



RSRA 741 1983 ROTOR CALIBRATION

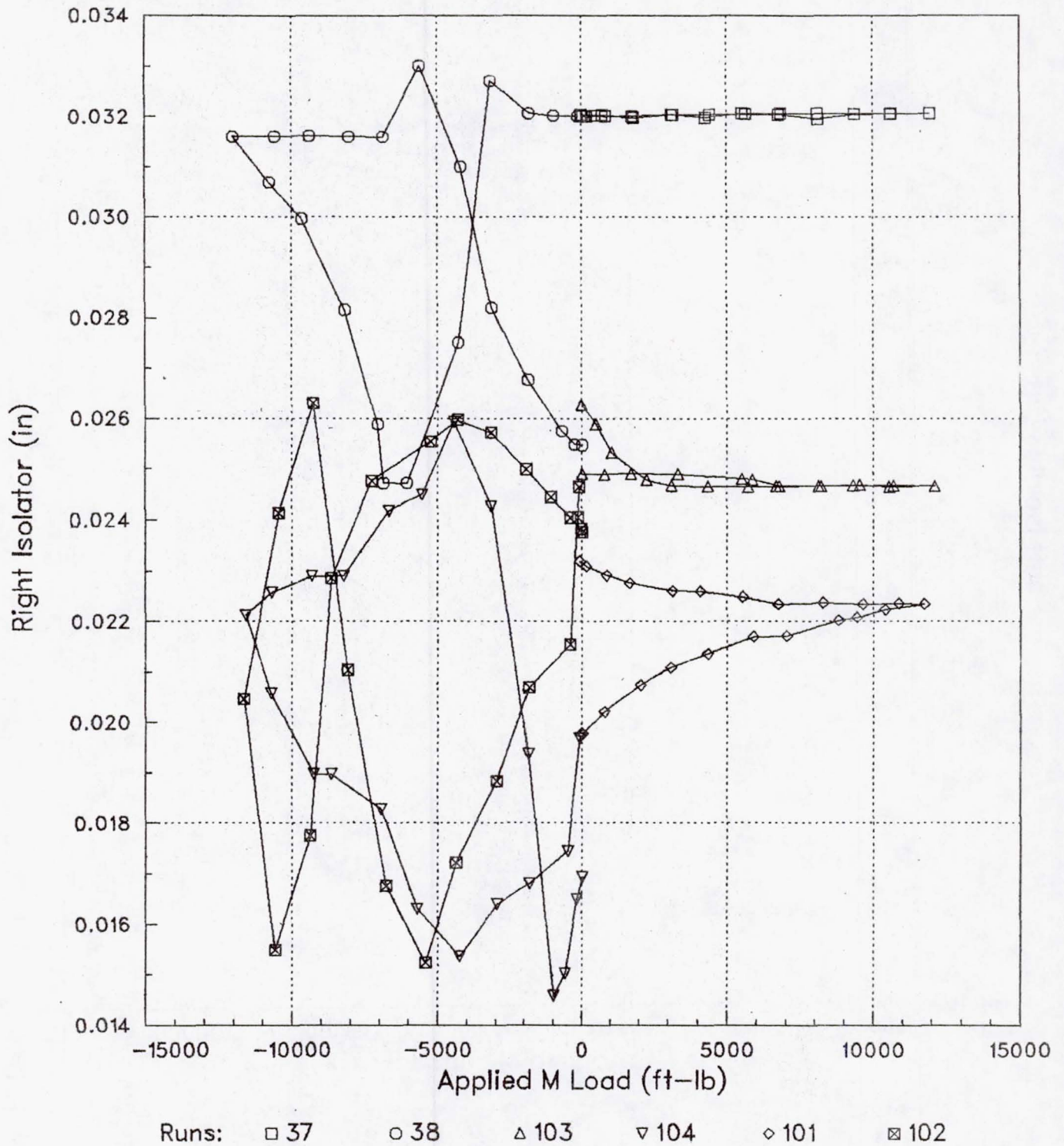
Applied M Load

Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

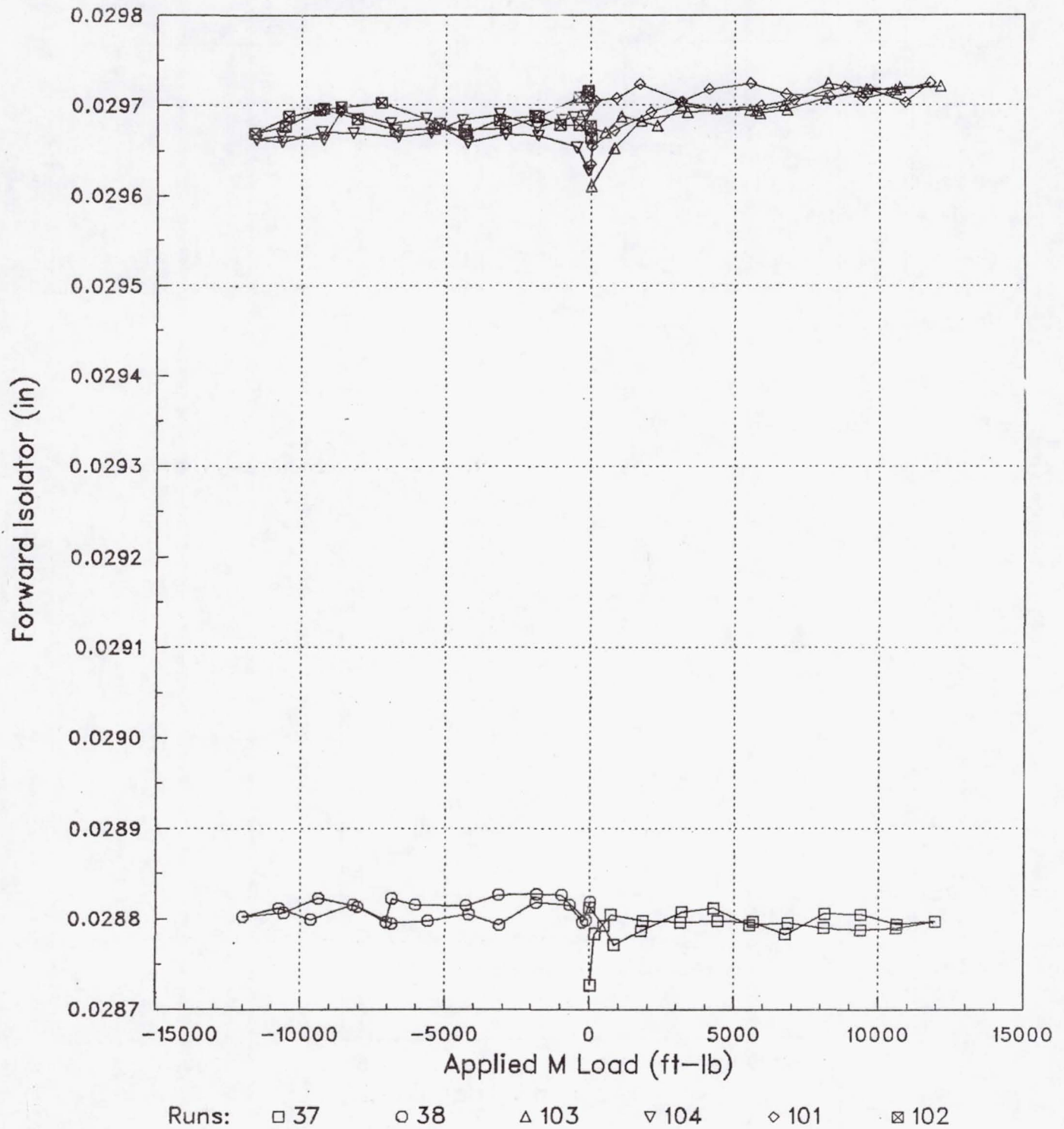
Applied M Load
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

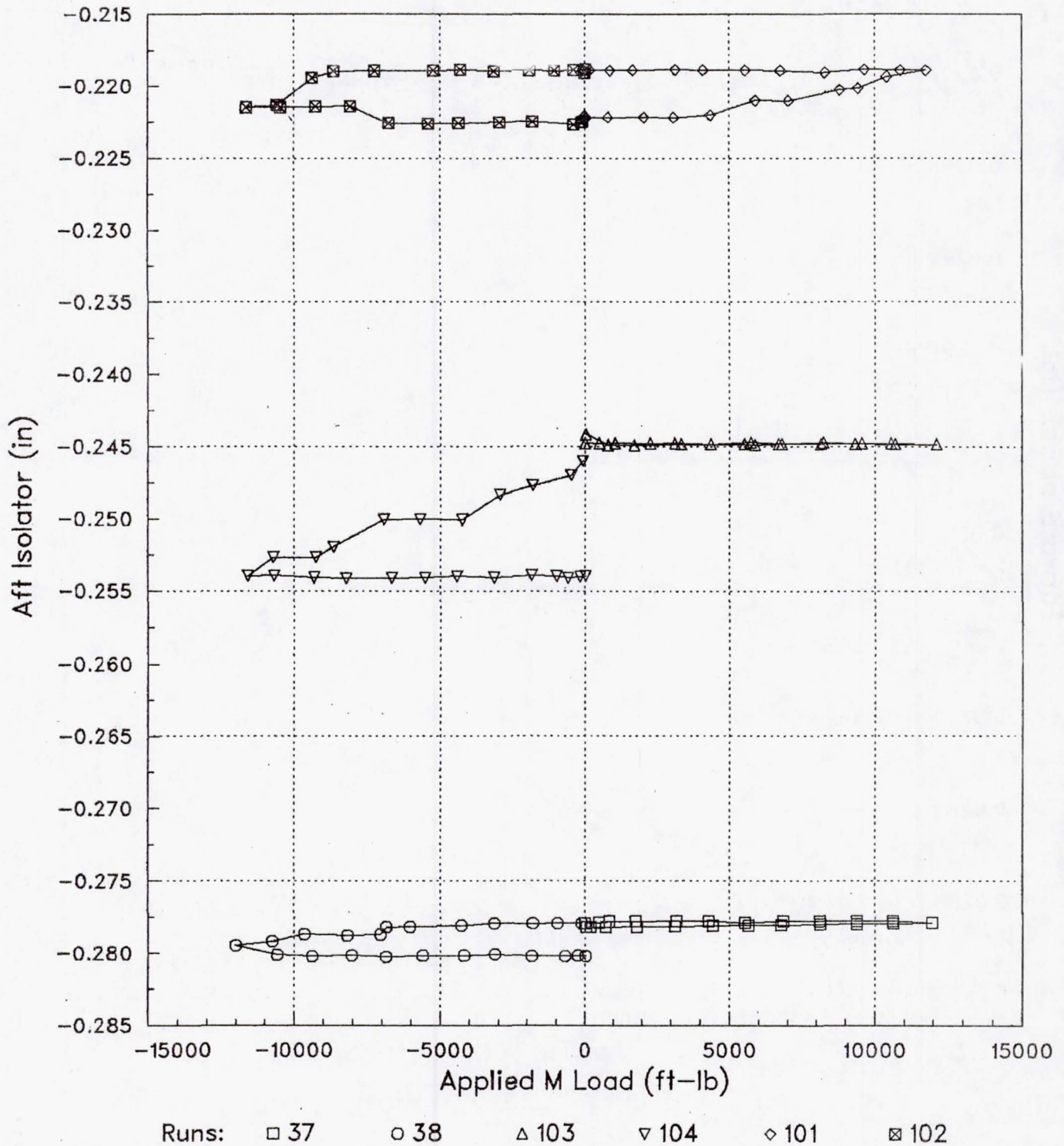
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

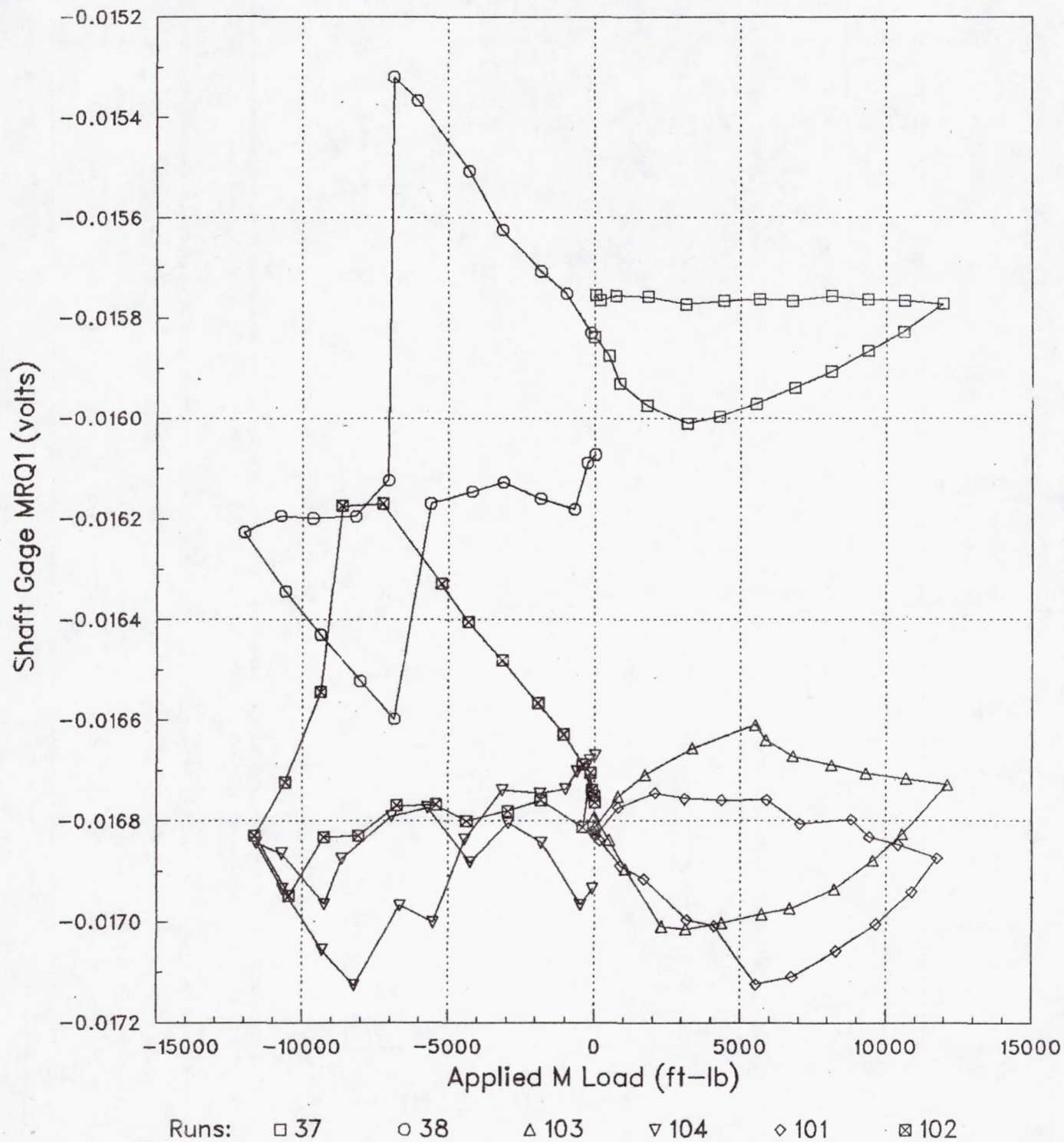
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

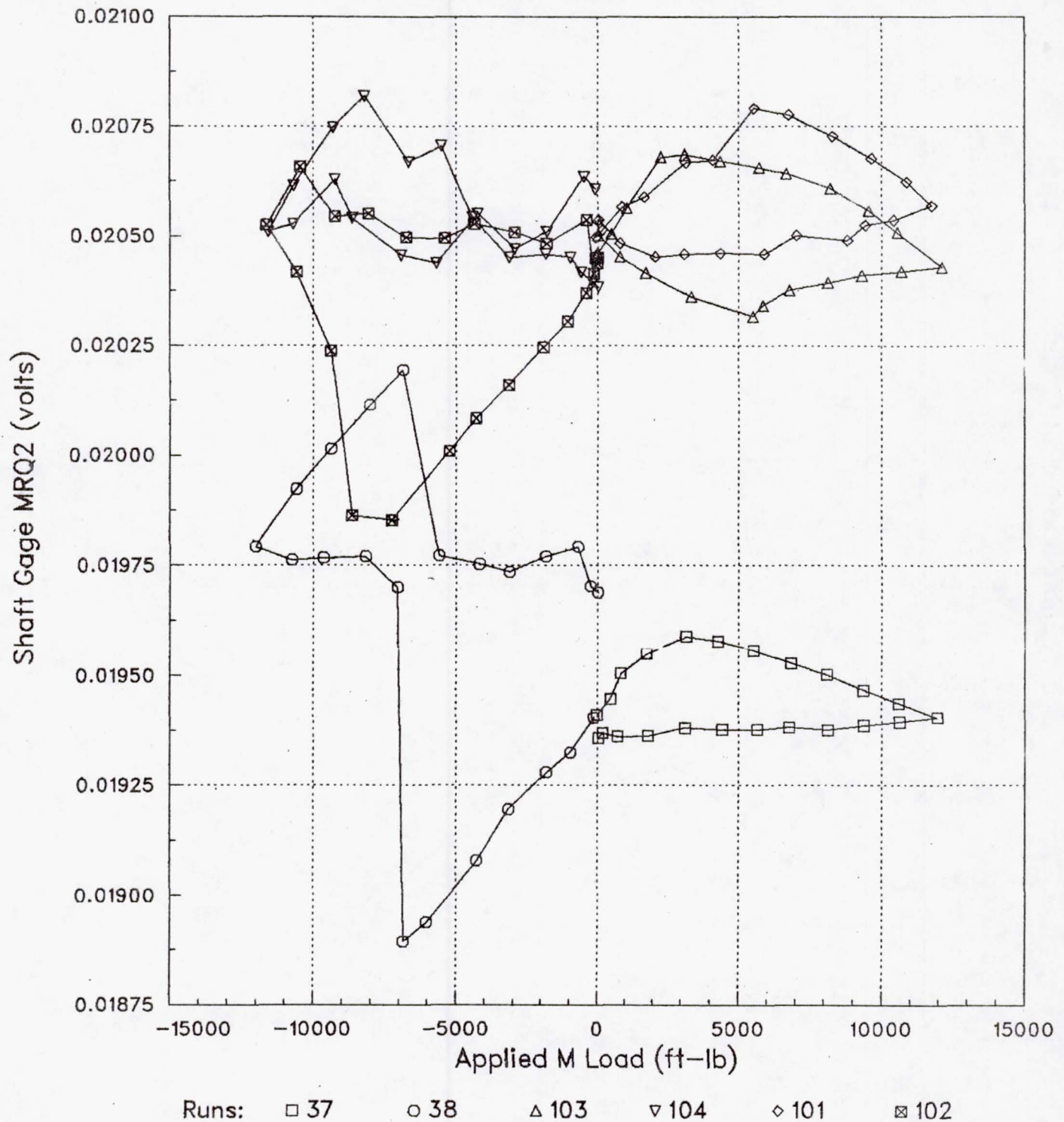
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

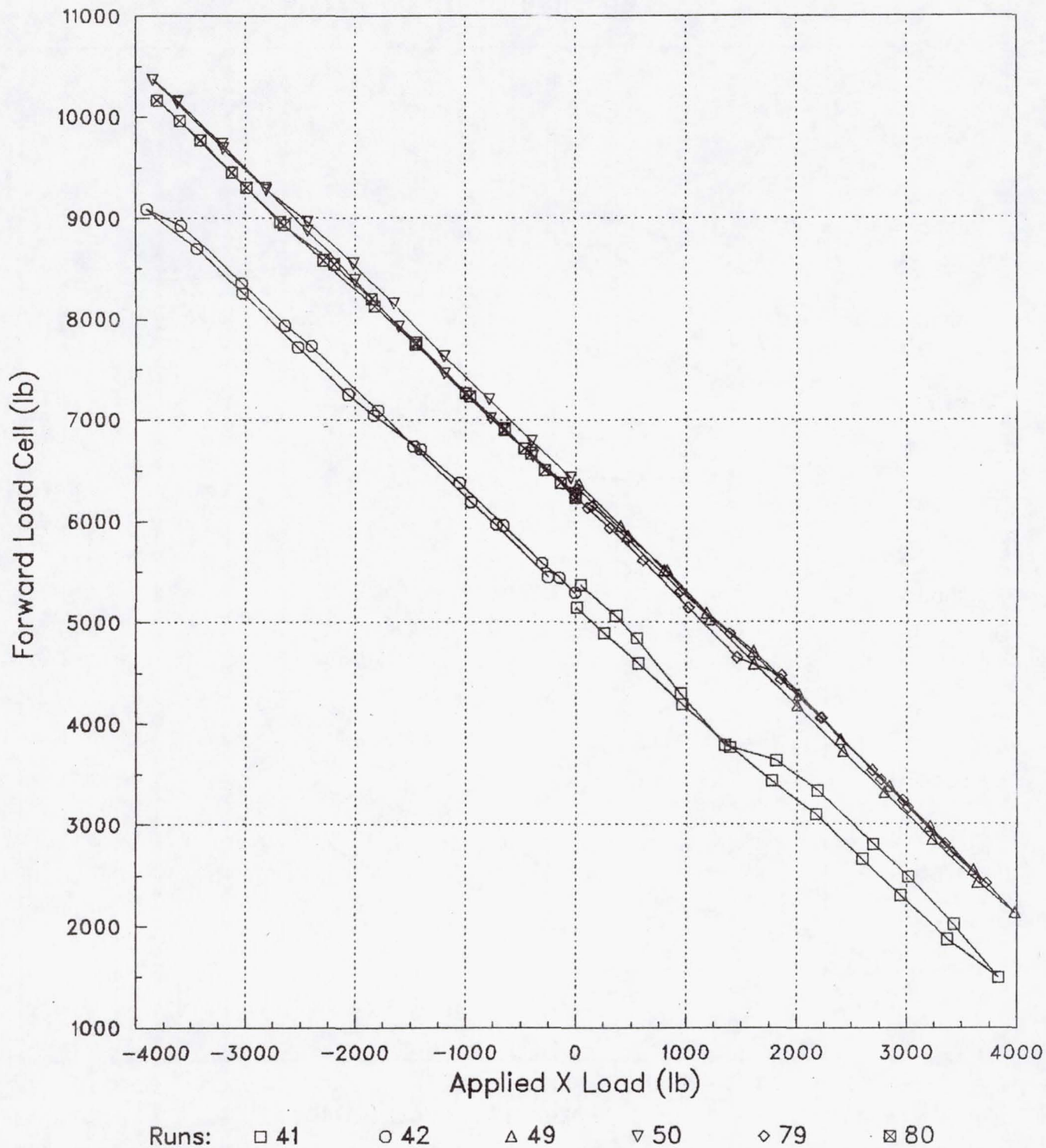
Constant Loads: Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

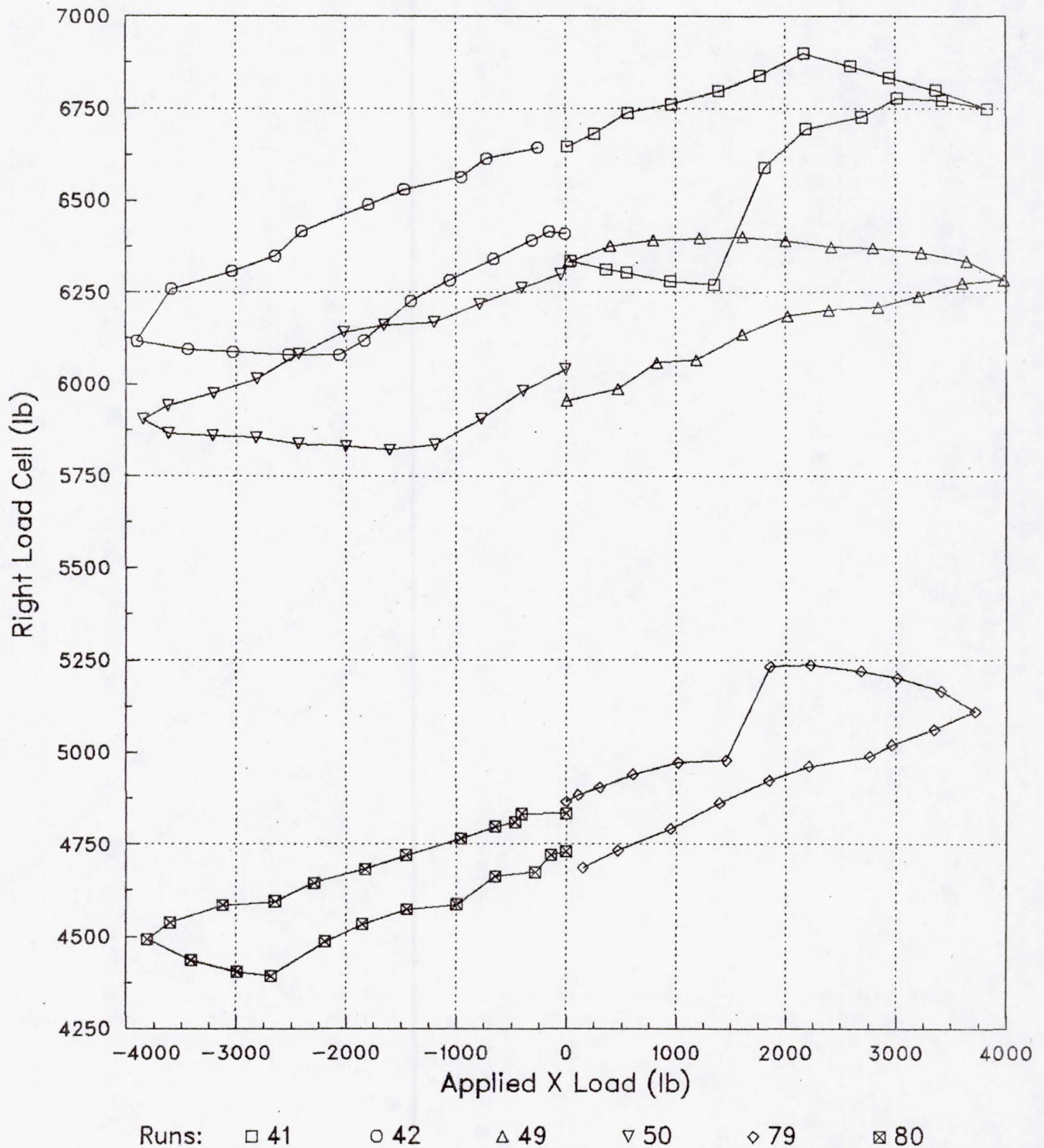
Applied X Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

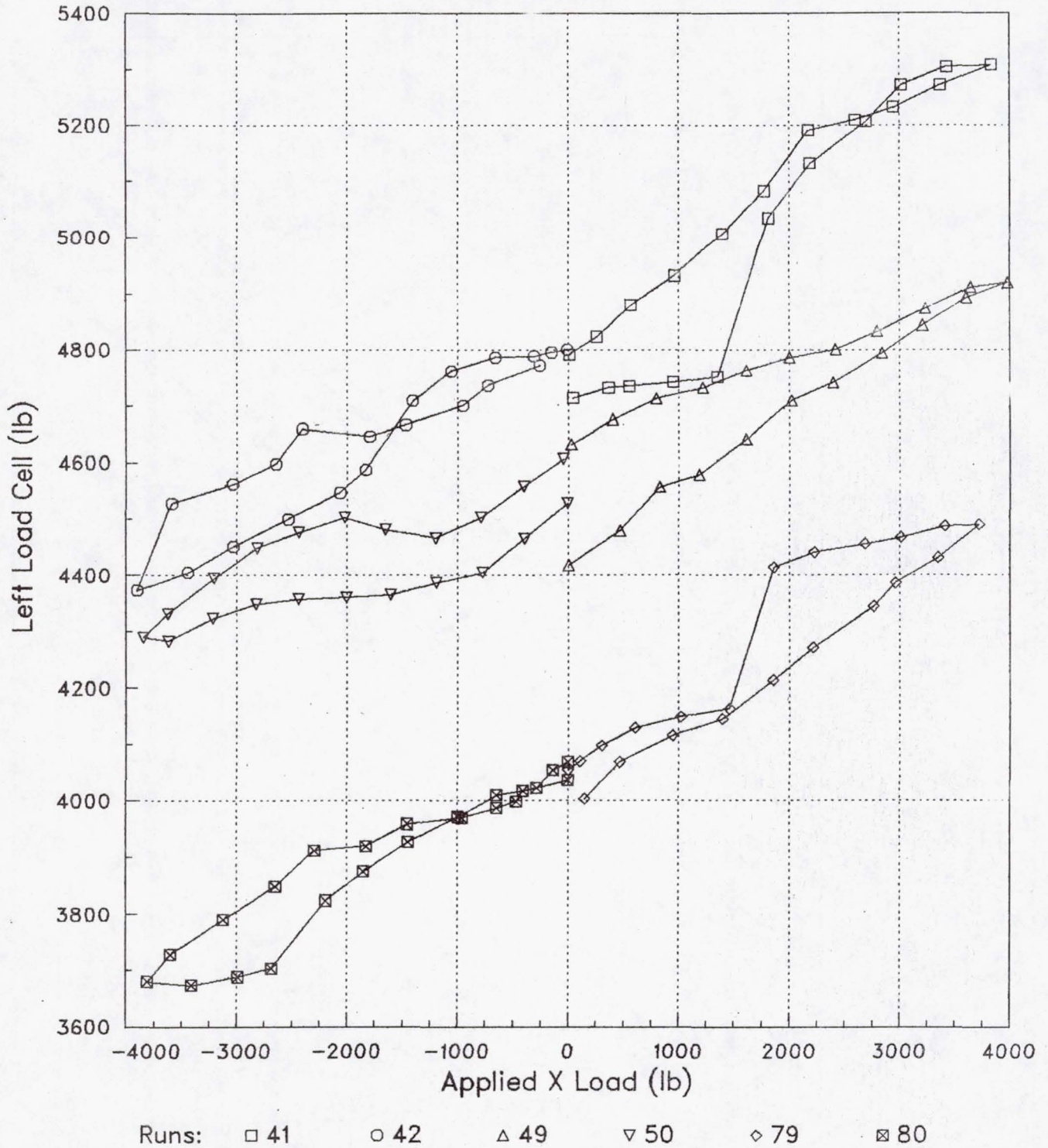
Applied X Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

Applied X Load

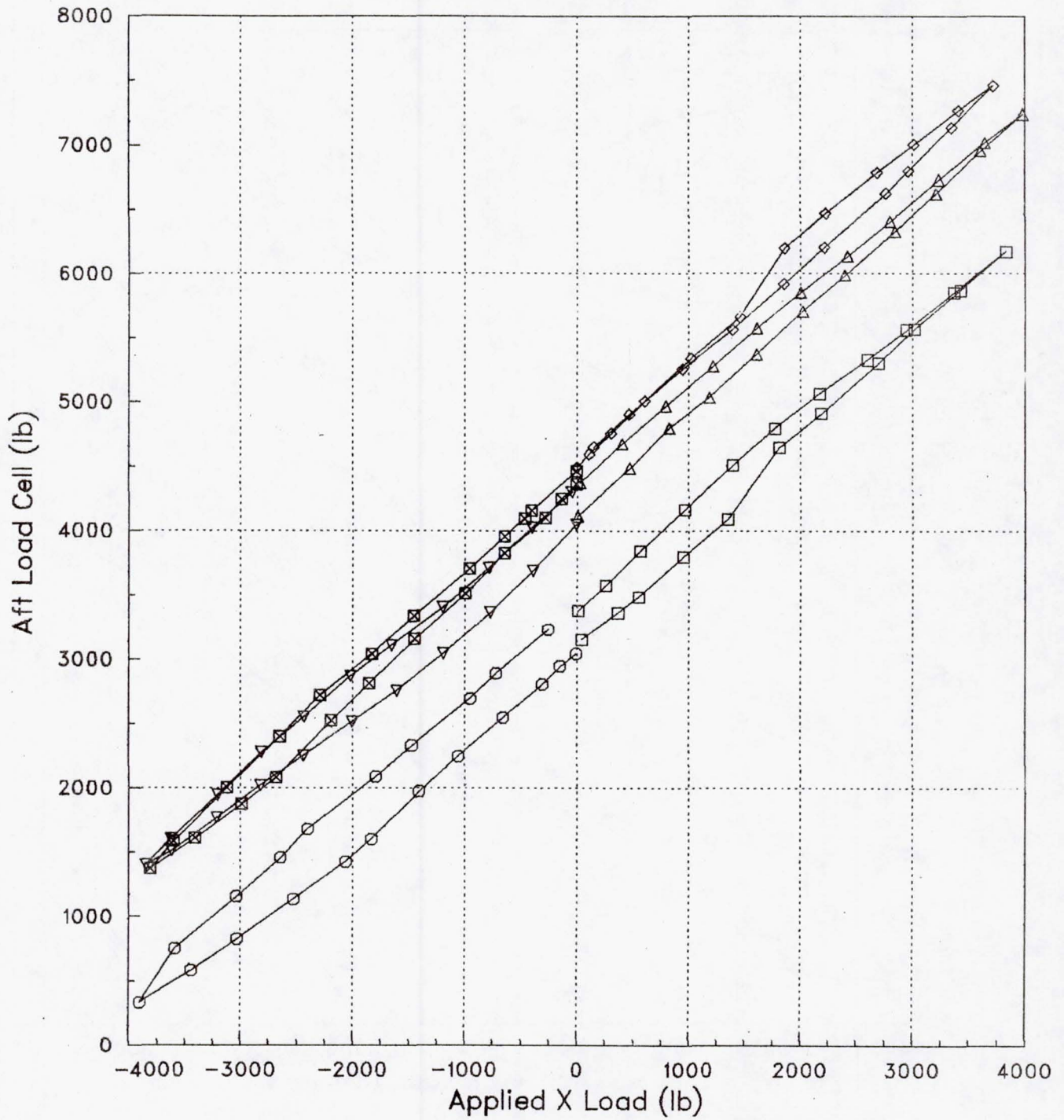
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

Applied X Load

Constant Loads: 50% Z, N

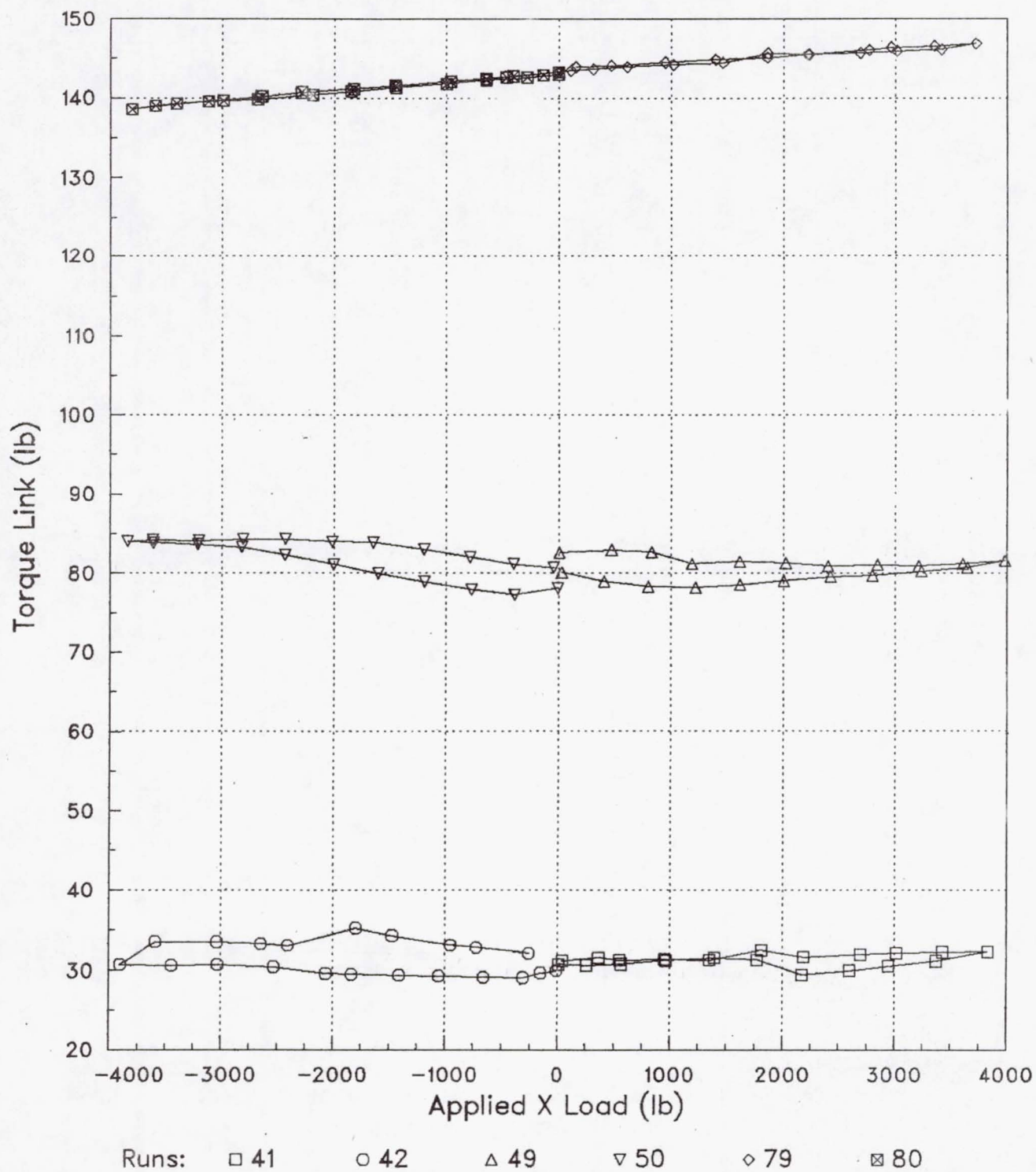


Runs: □ 41 ○ 42 △ 49 ▽ 50 ◇ 79 ⓧ 80

RSRA 741 1983 ROTOR CALIBRATION

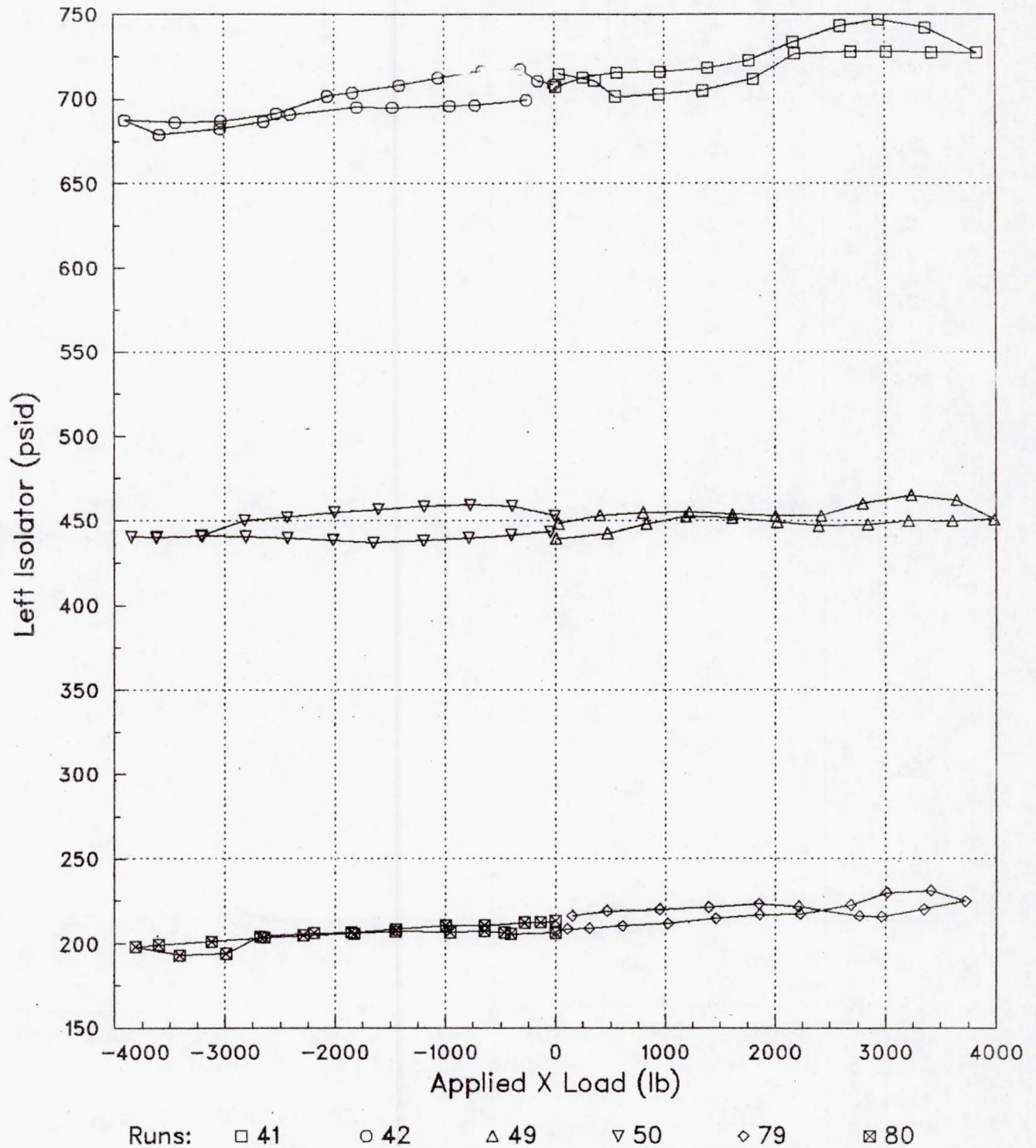
Applied X Load

Constant Loads: 50% Z, N



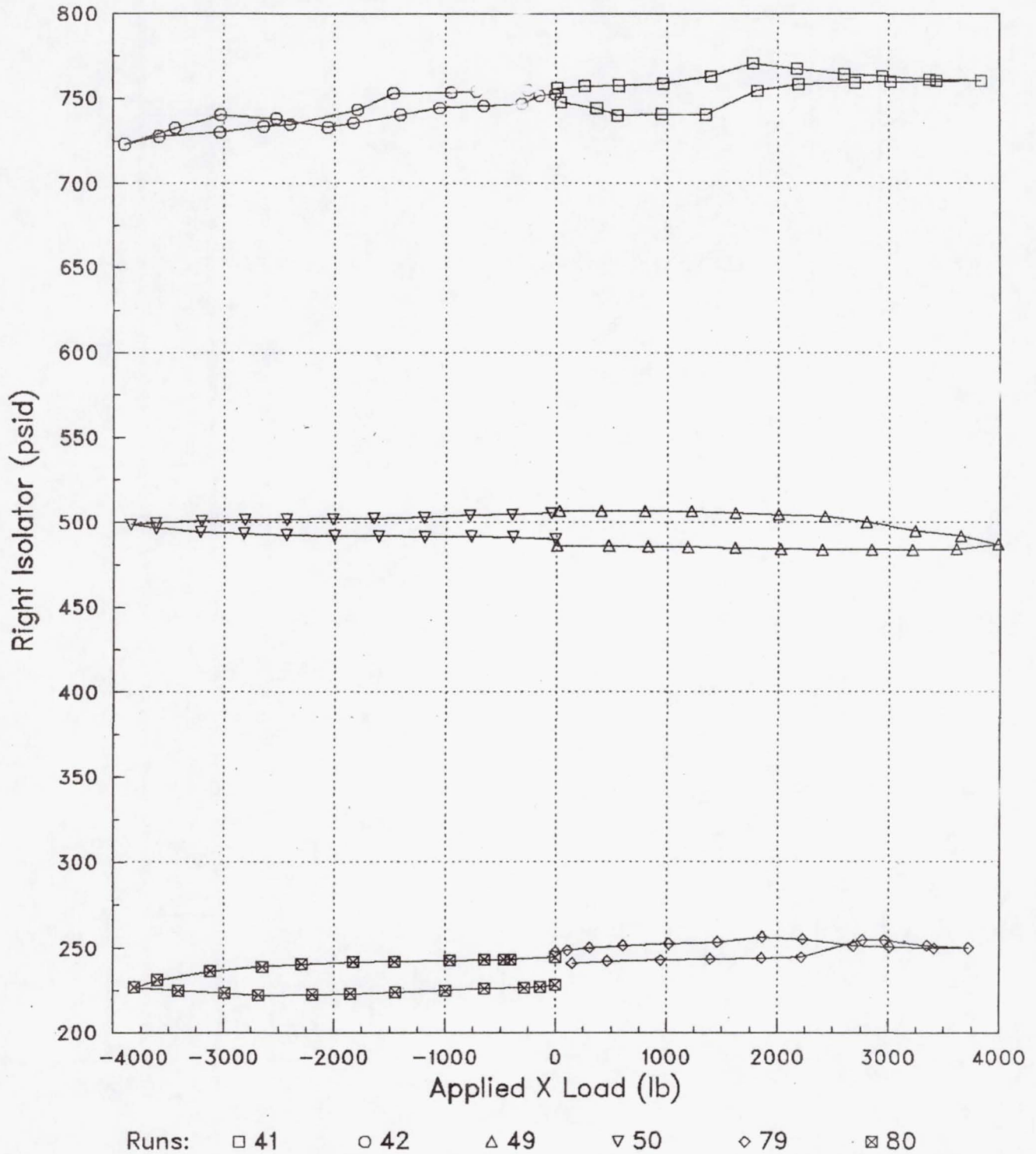
RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: 50% Z, N



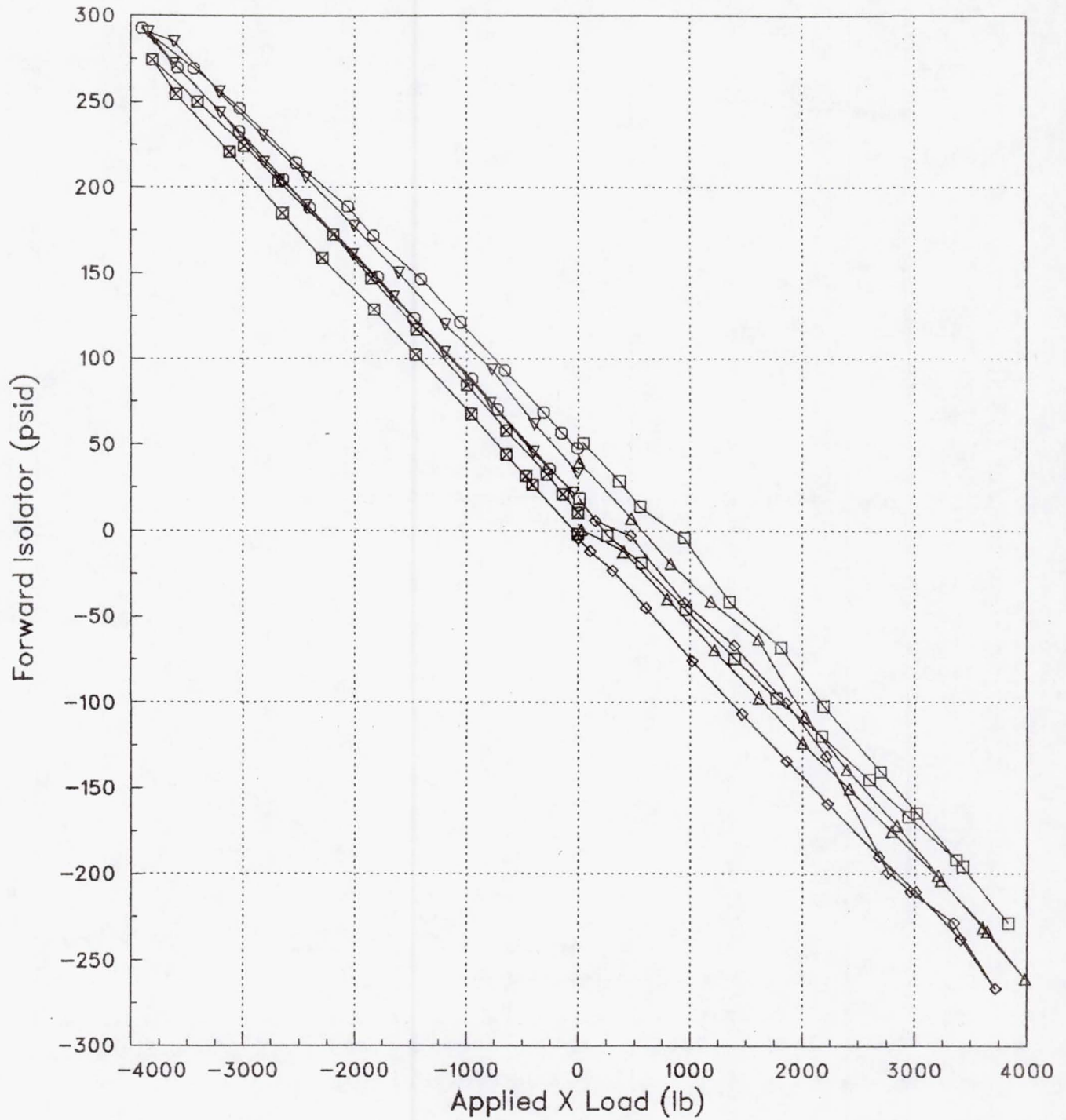
RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: 50% Z, N

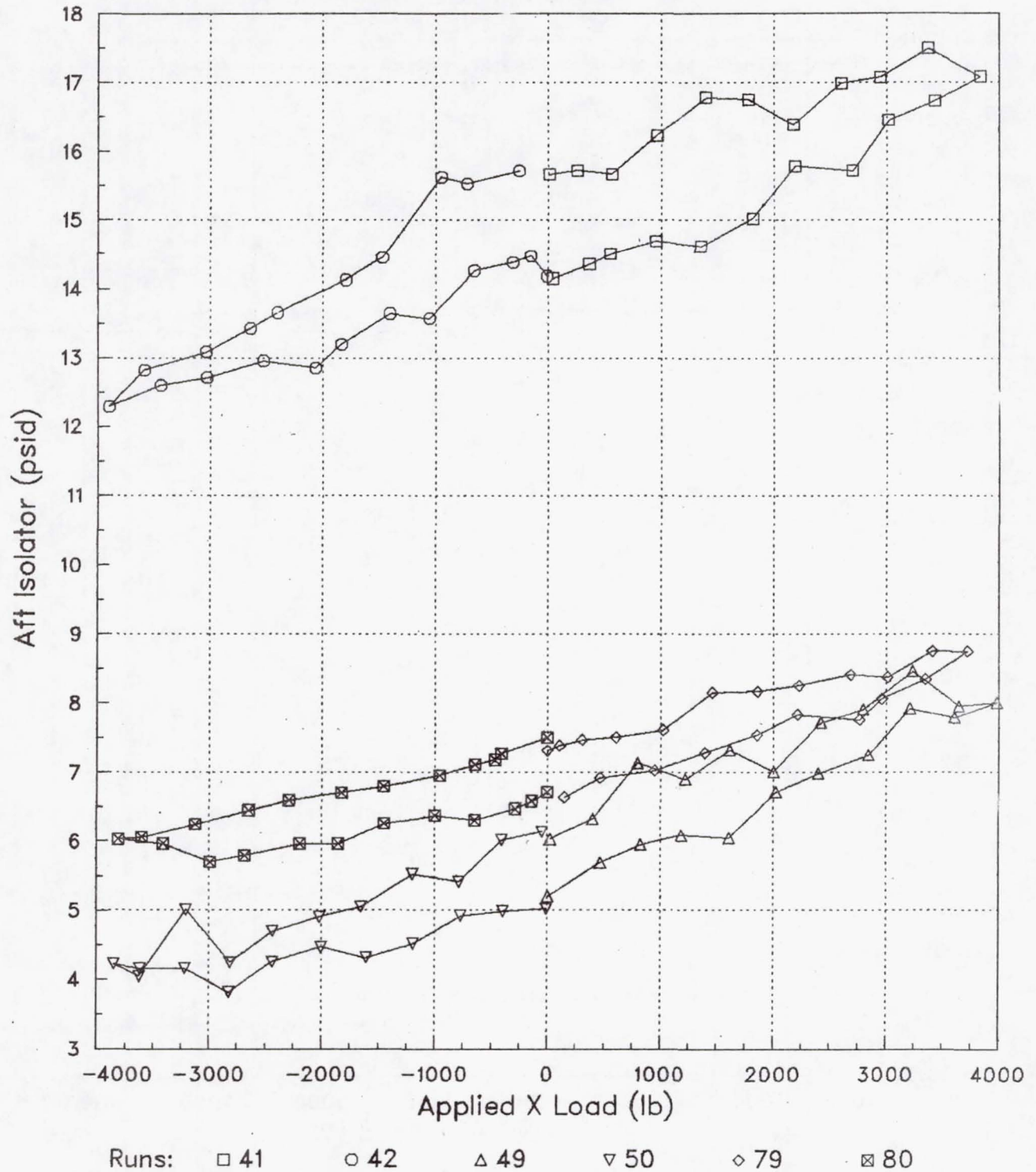


Runs: □ 41 ○ 42 △ 49 ▽ 50 ◇ 79 ⊠ 80

RSRA 741 1983 ROTOR CALIBRATION

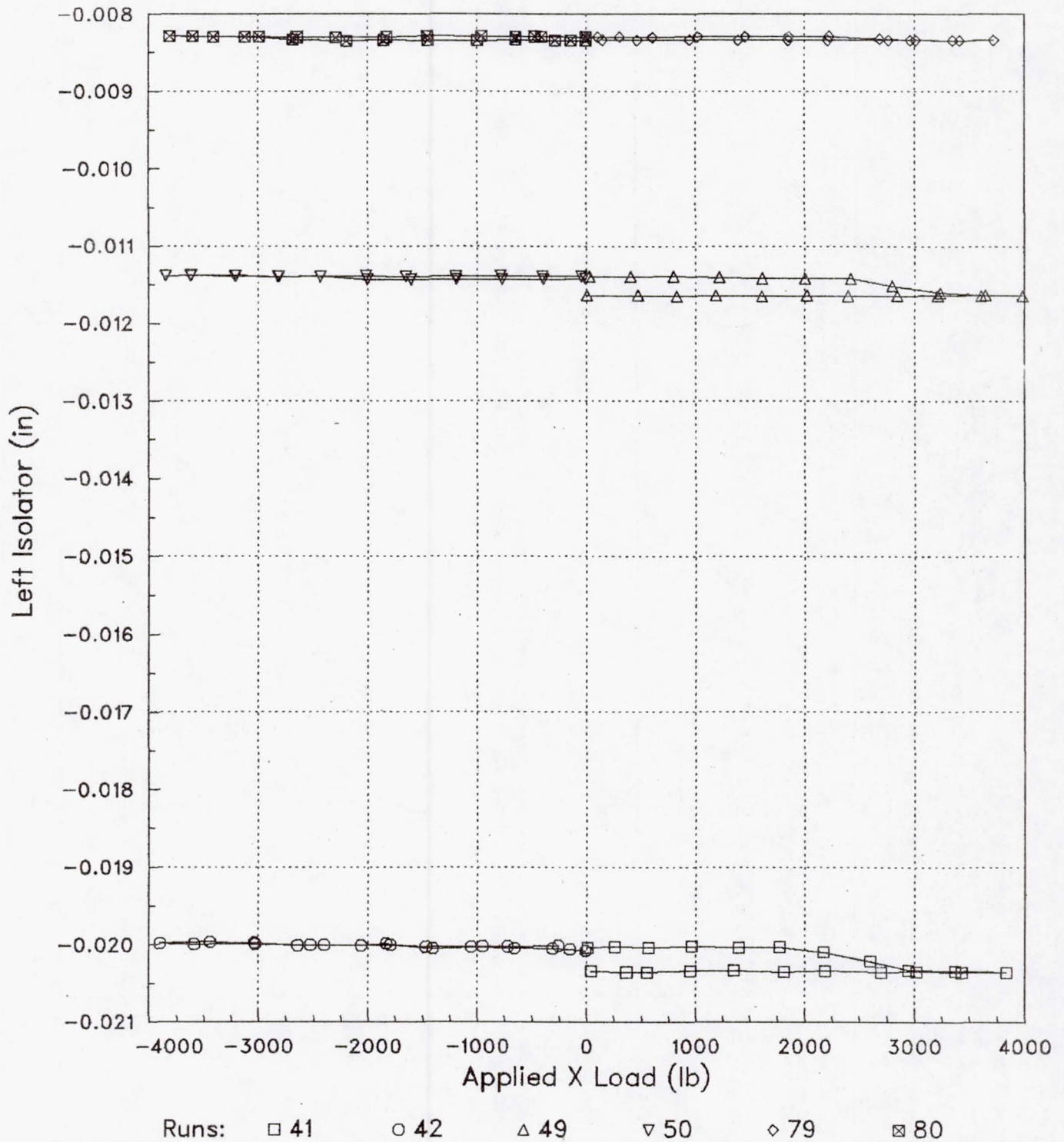
Applied X Load

Constant Loads: 50% Z, N



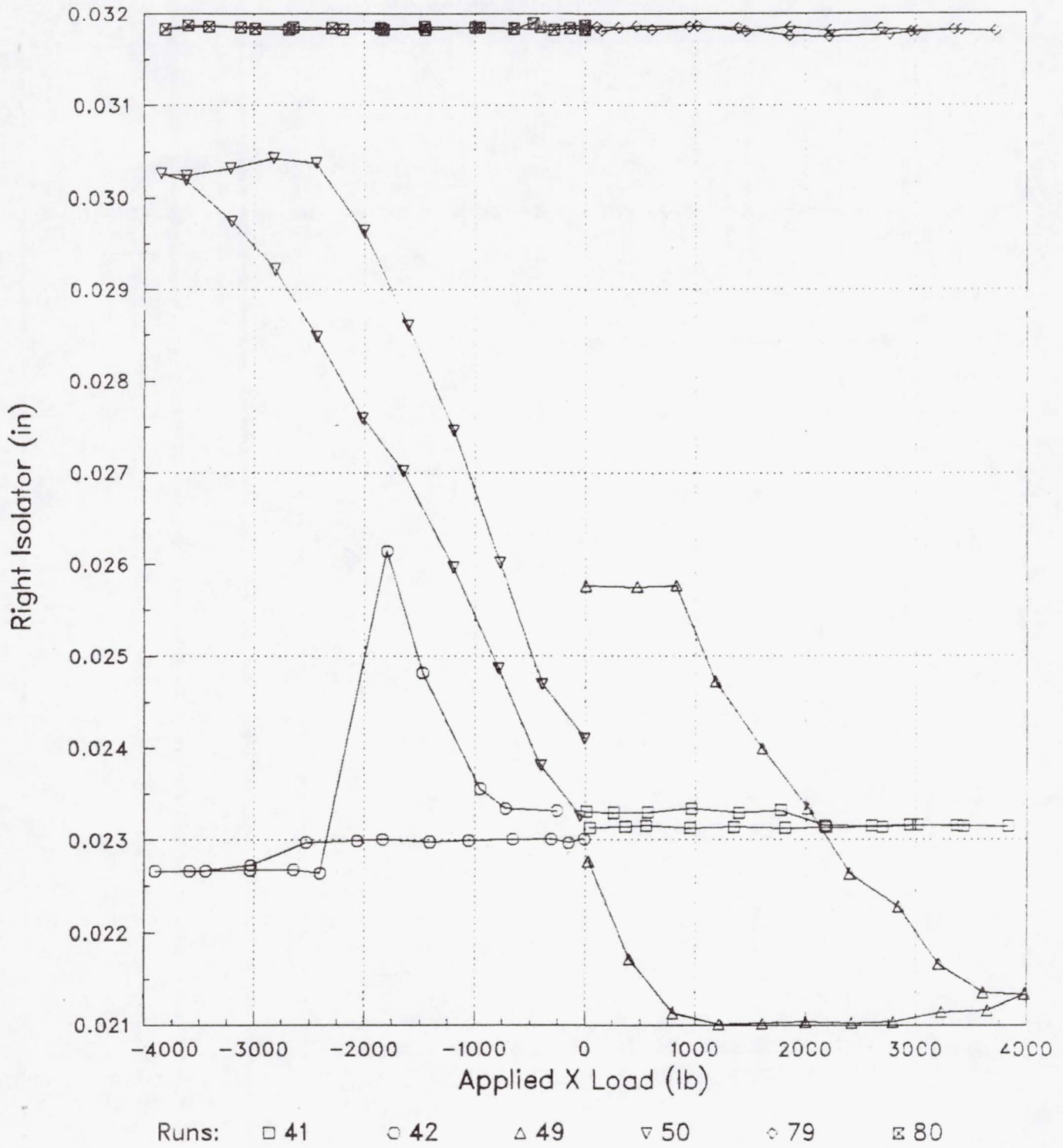
RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: 50% Z, N



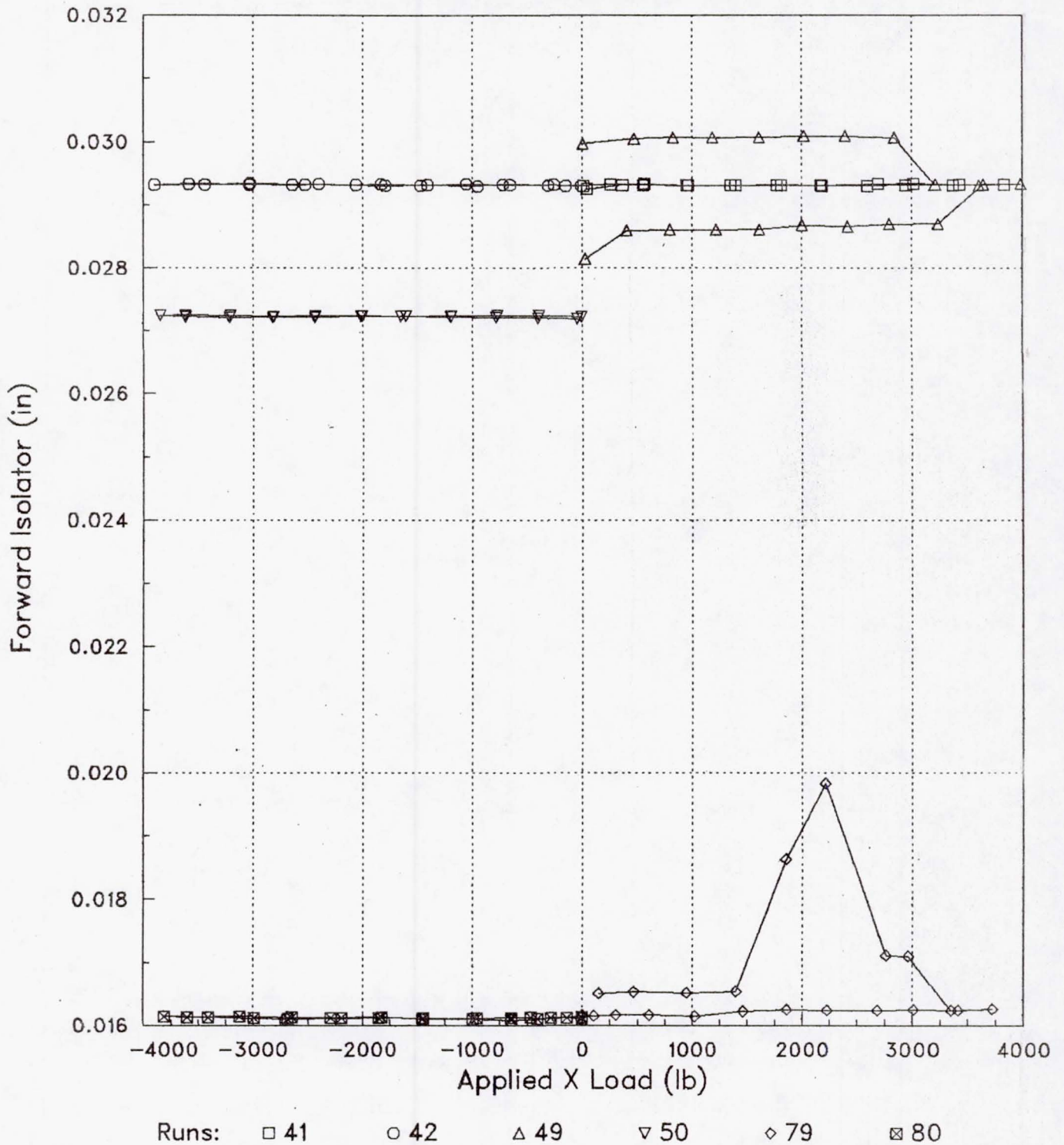
RSRA 741 1983 ROTOR CALIBRATION

Applied X Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

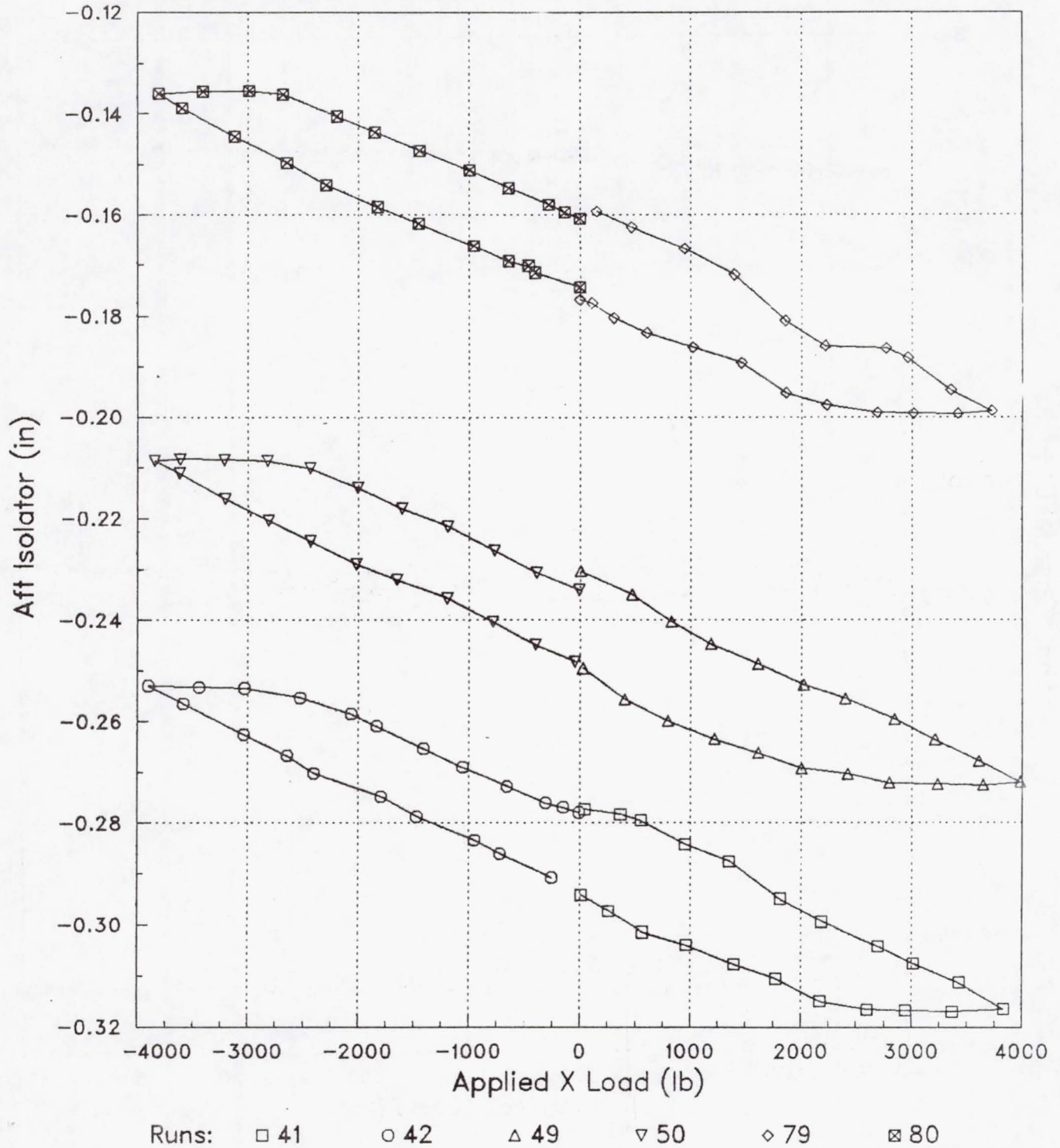
Applied X Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

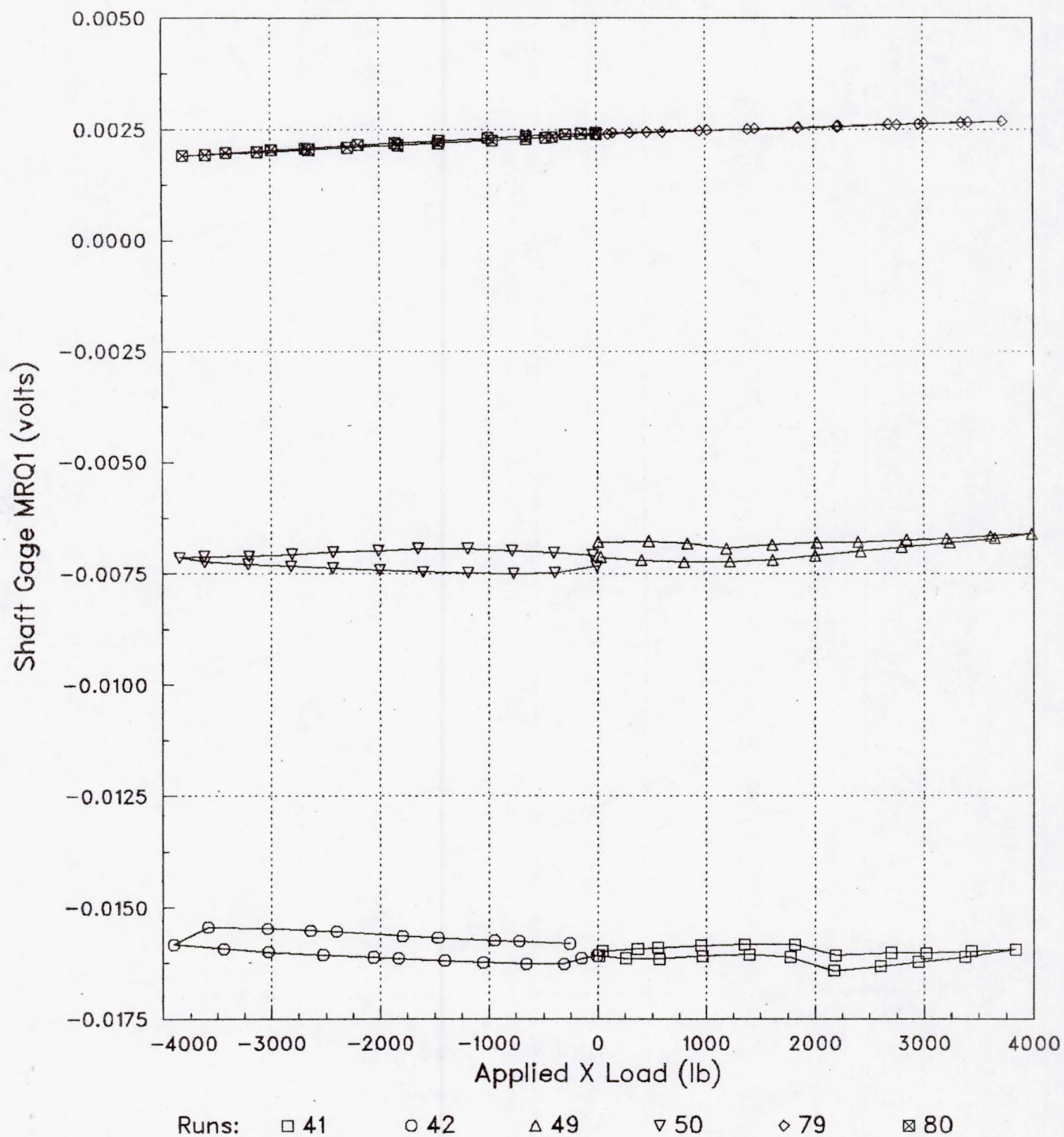
Applied X Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

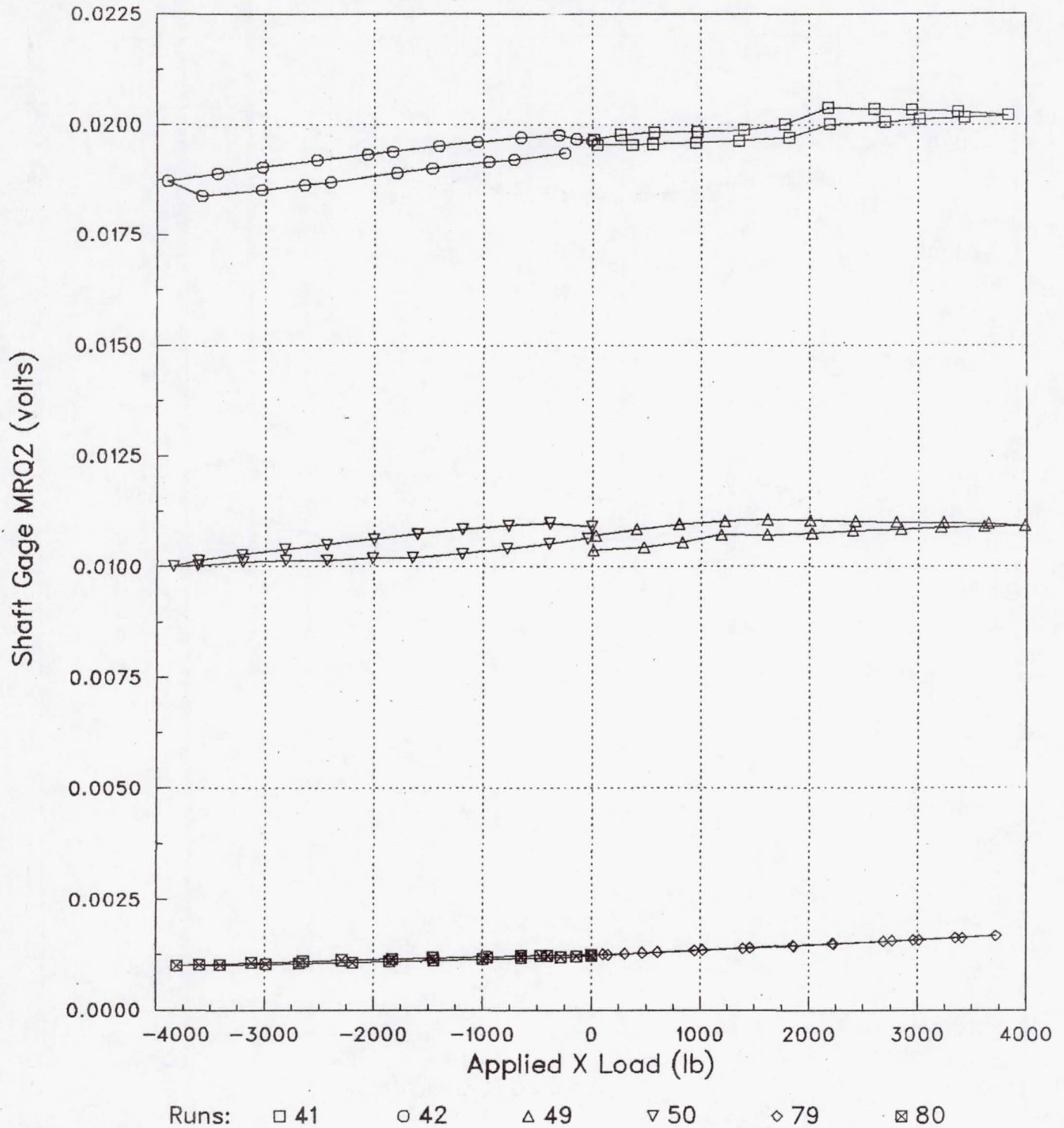
Applied X Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

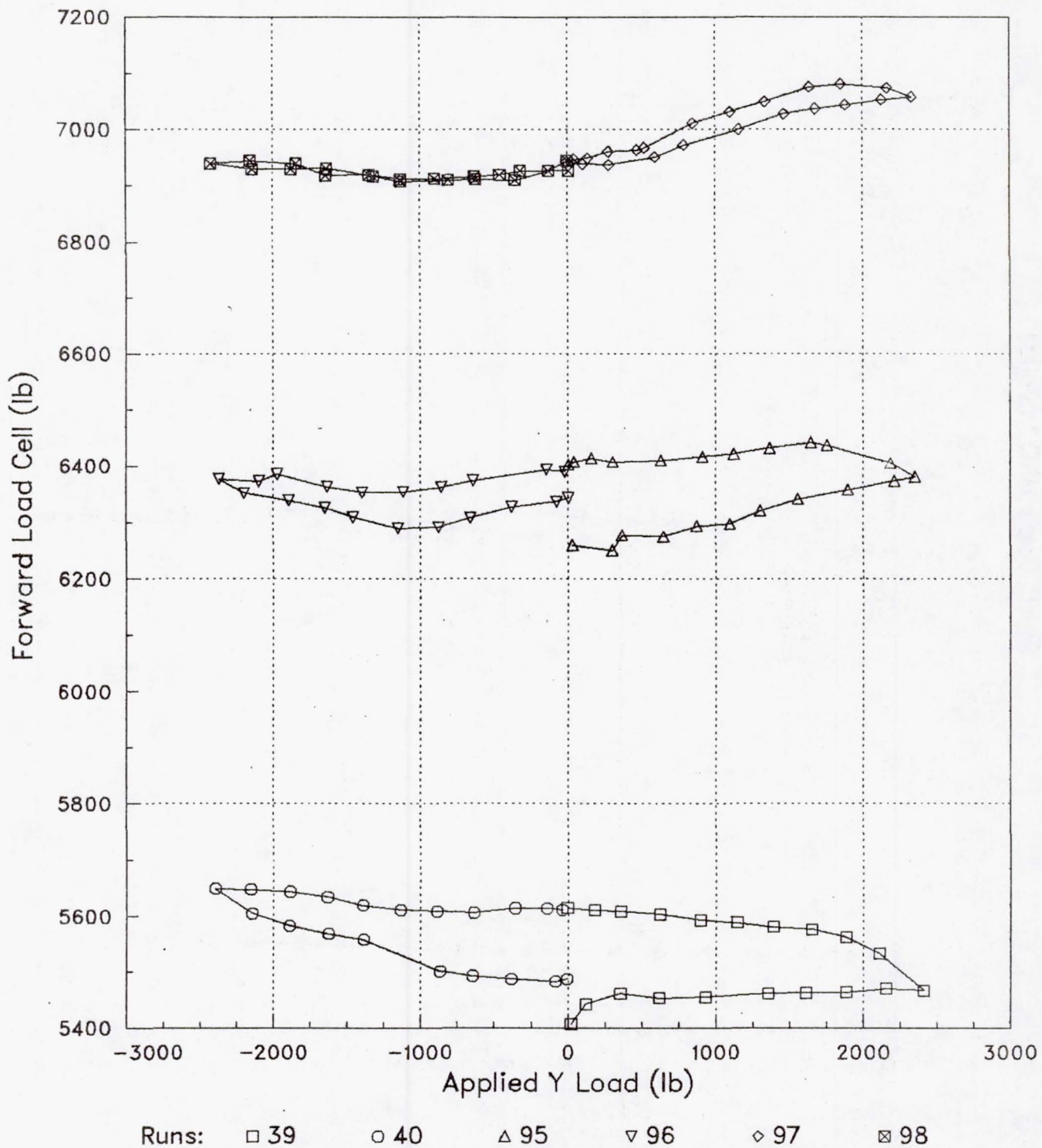
Applied X Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

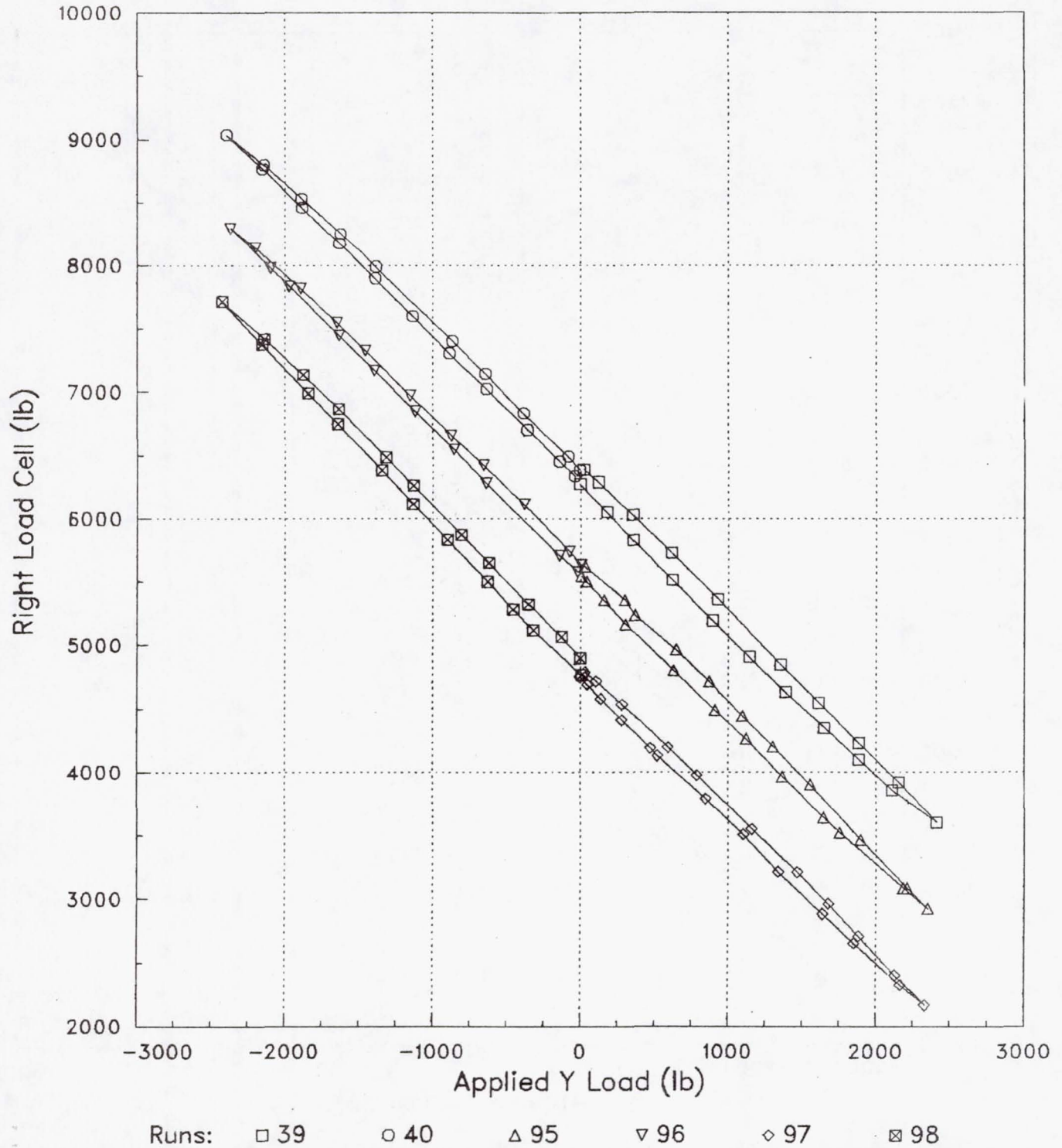
Applied Y Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

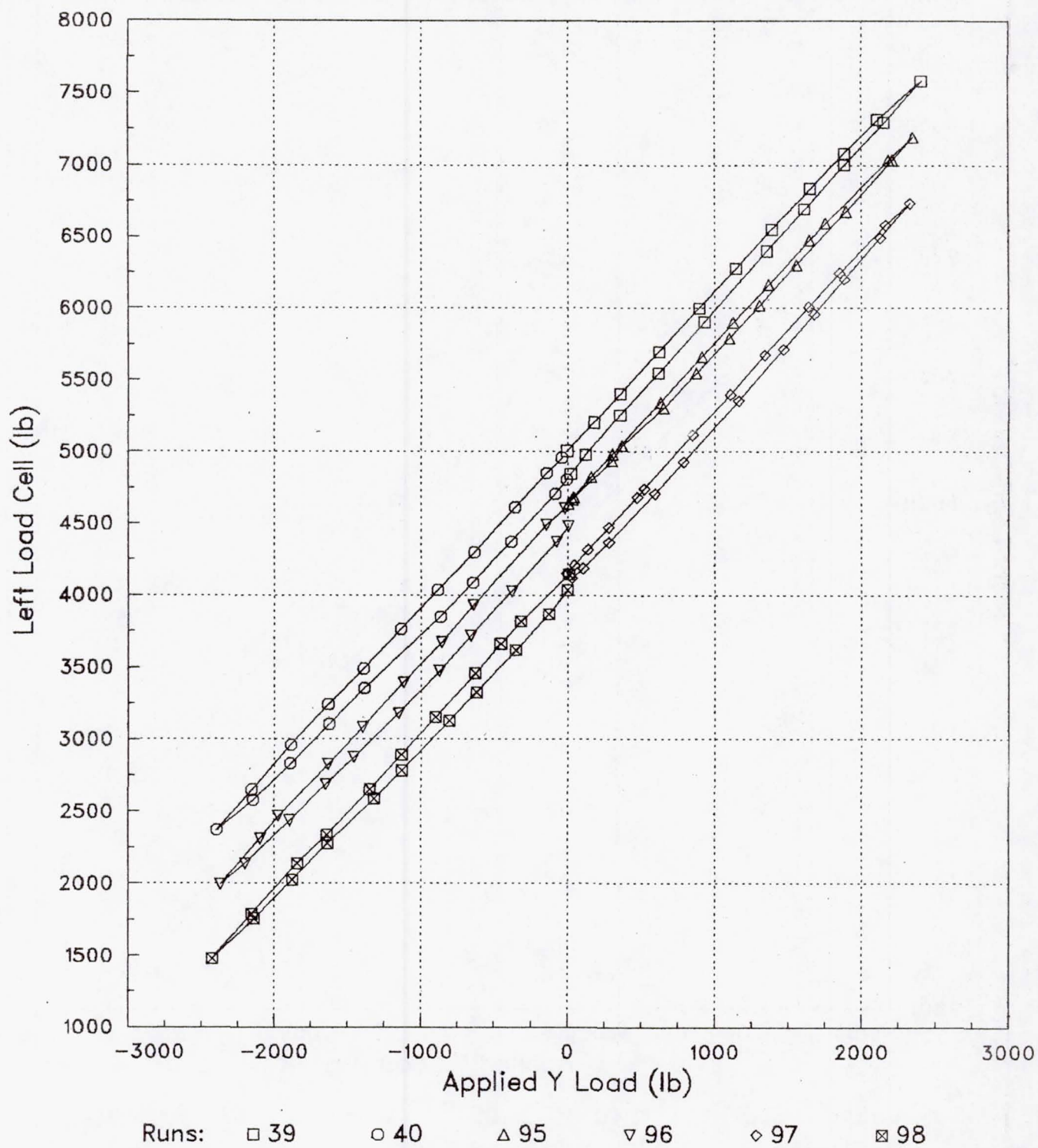
Applied Y Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

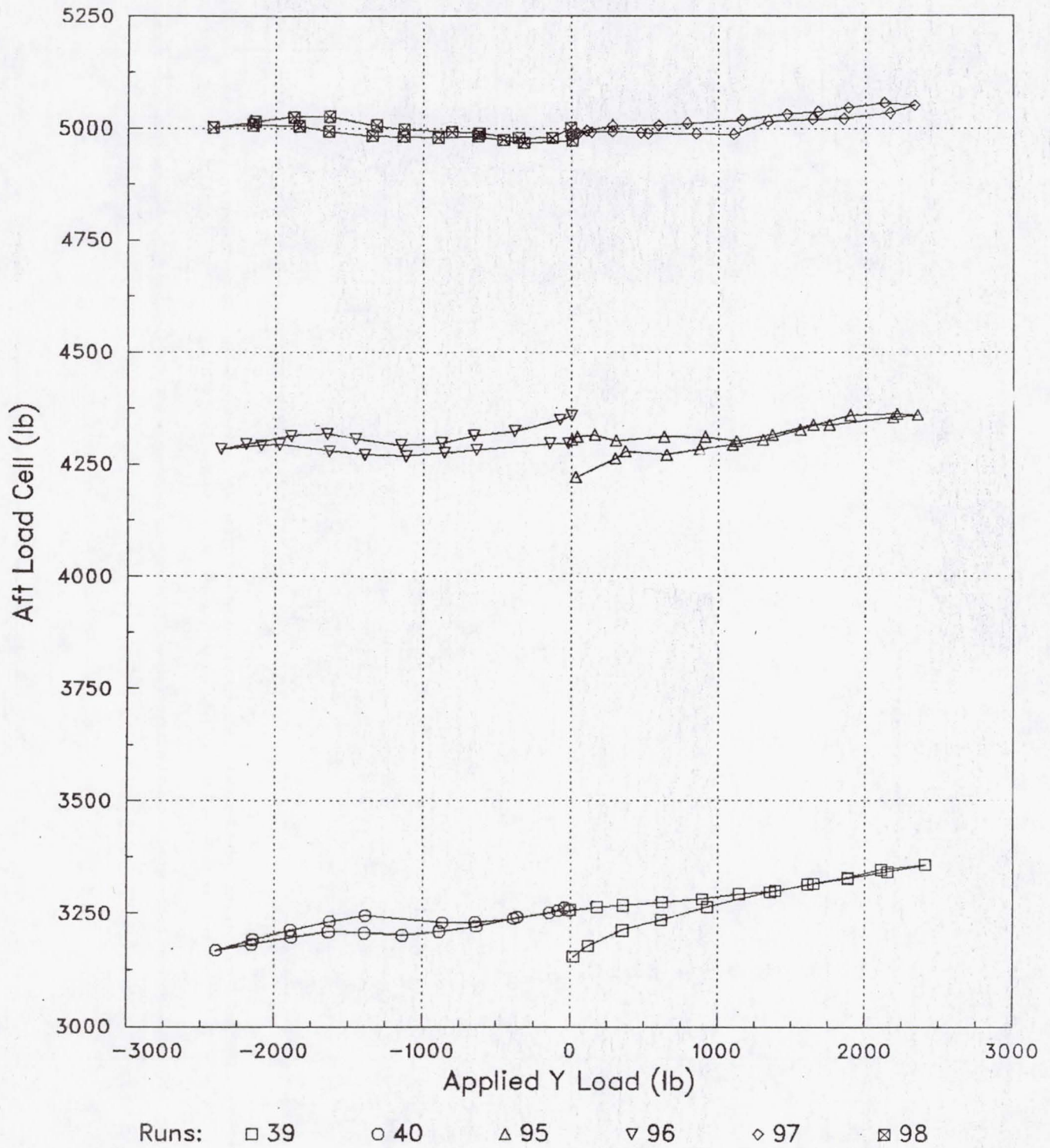
Applied Y Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

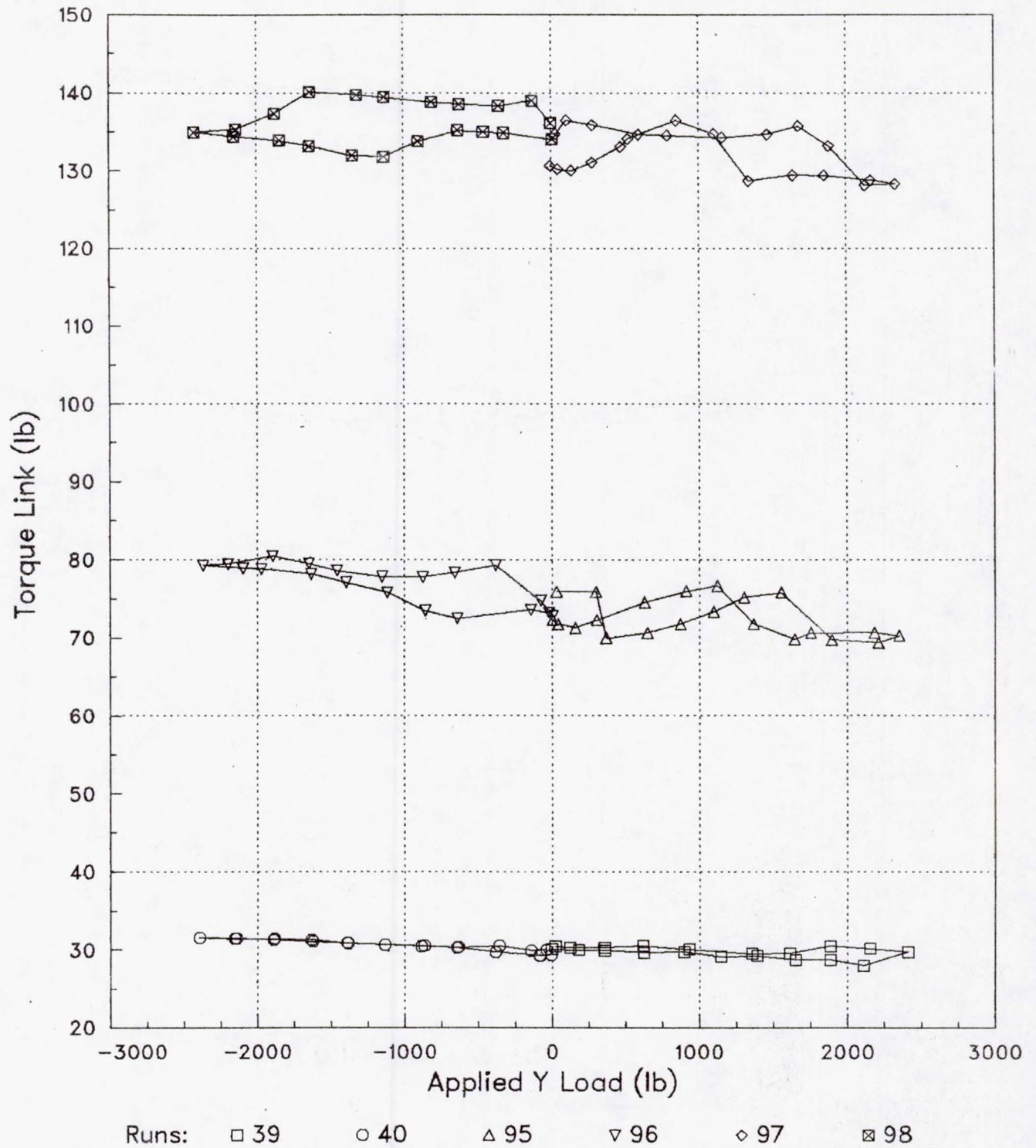
Applied Y Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

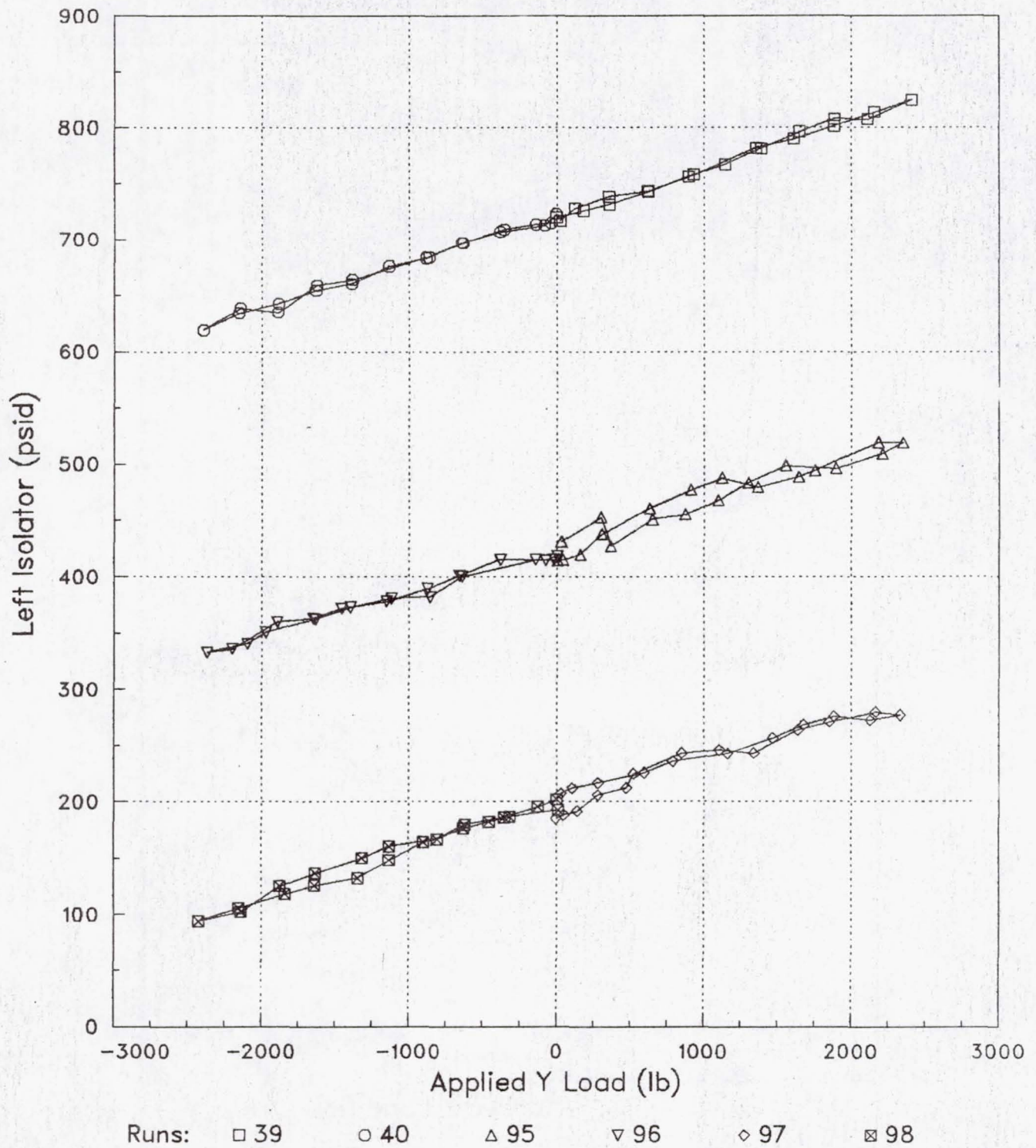
Applied Y Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

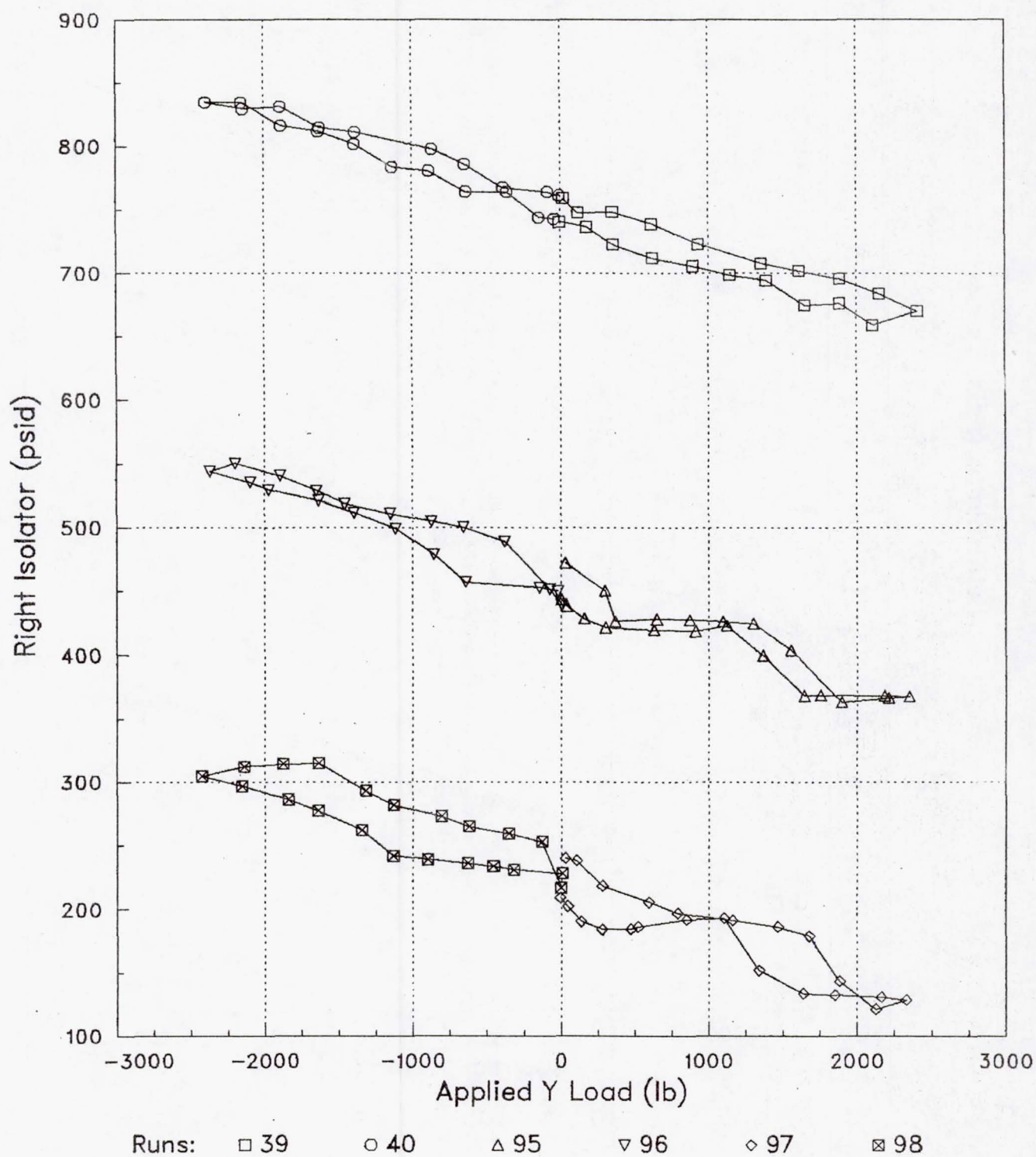
Applied Y Load

Constant Loads: 50% Z, N

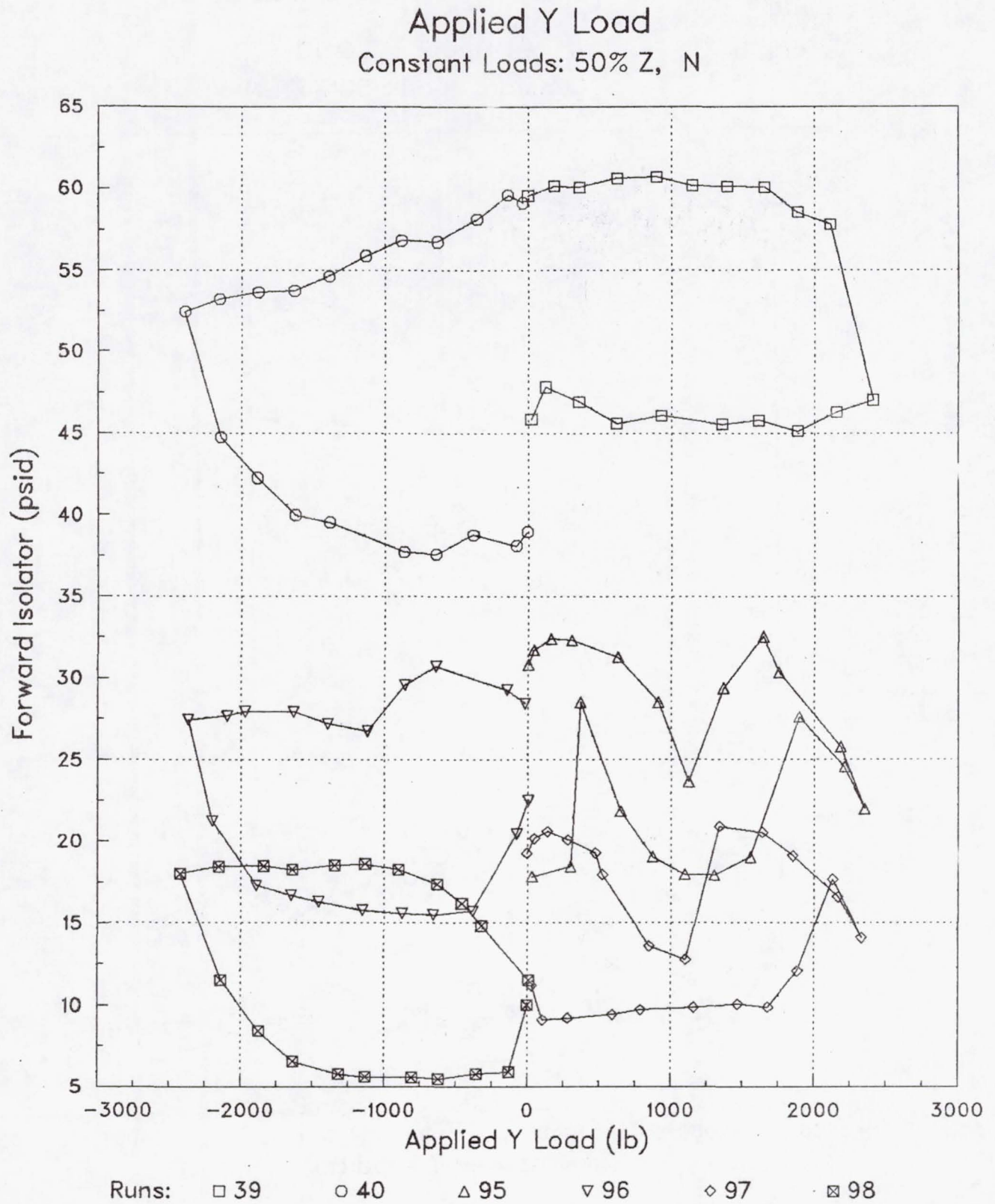


RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: 50% Z, N

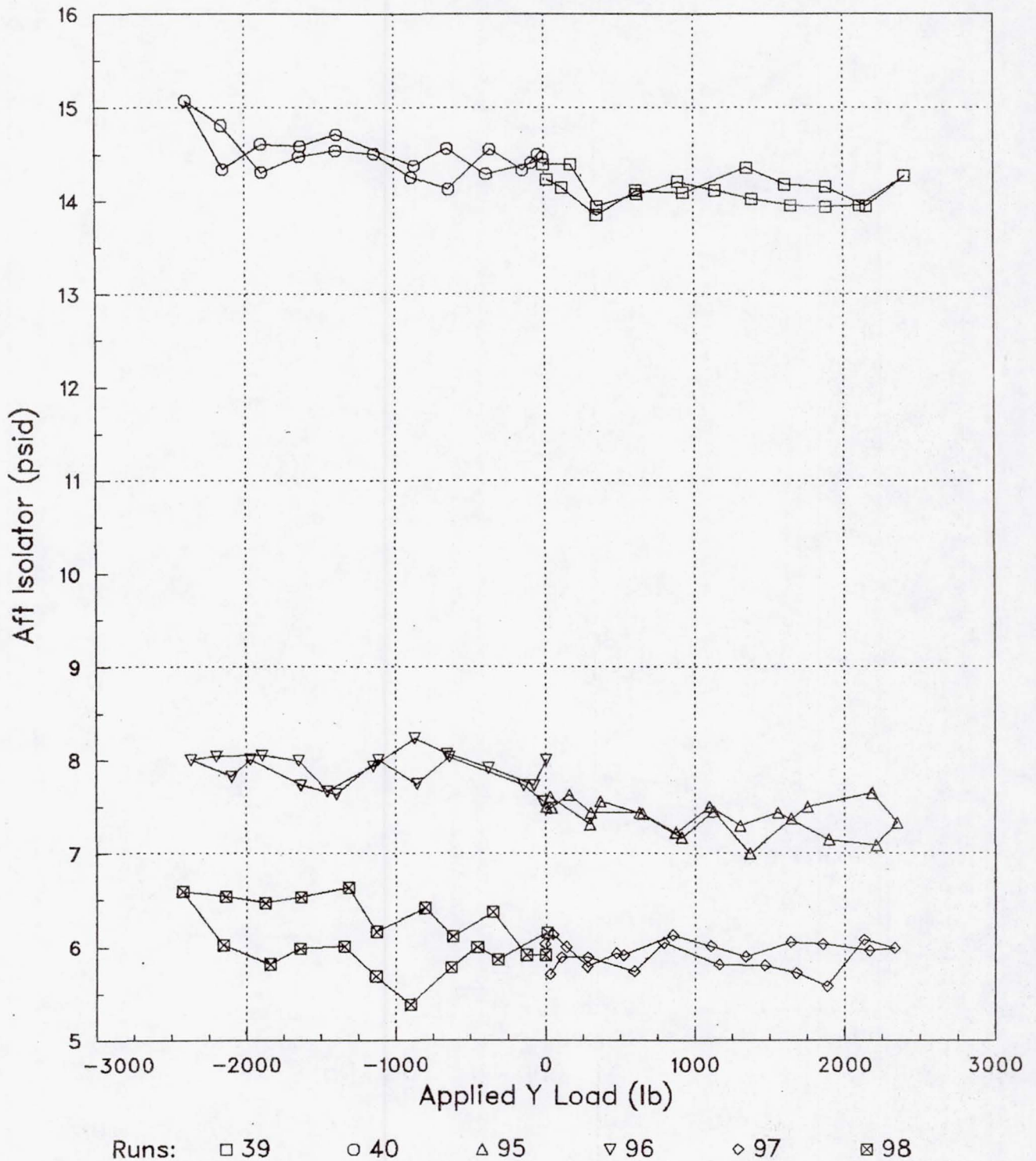


RSRA 741 1983 ROTOR CALIBRATION



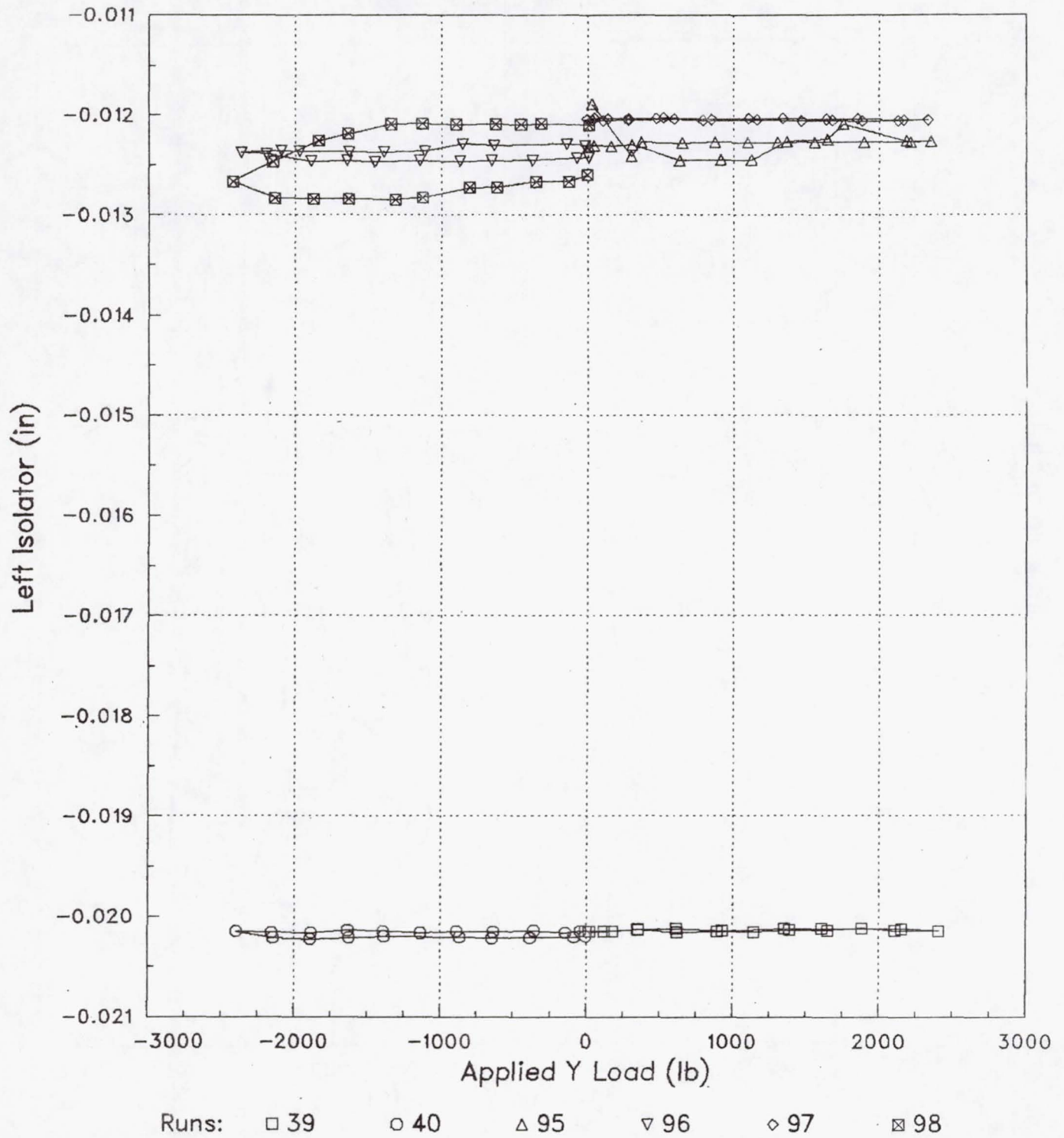
RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: 50% Z, N



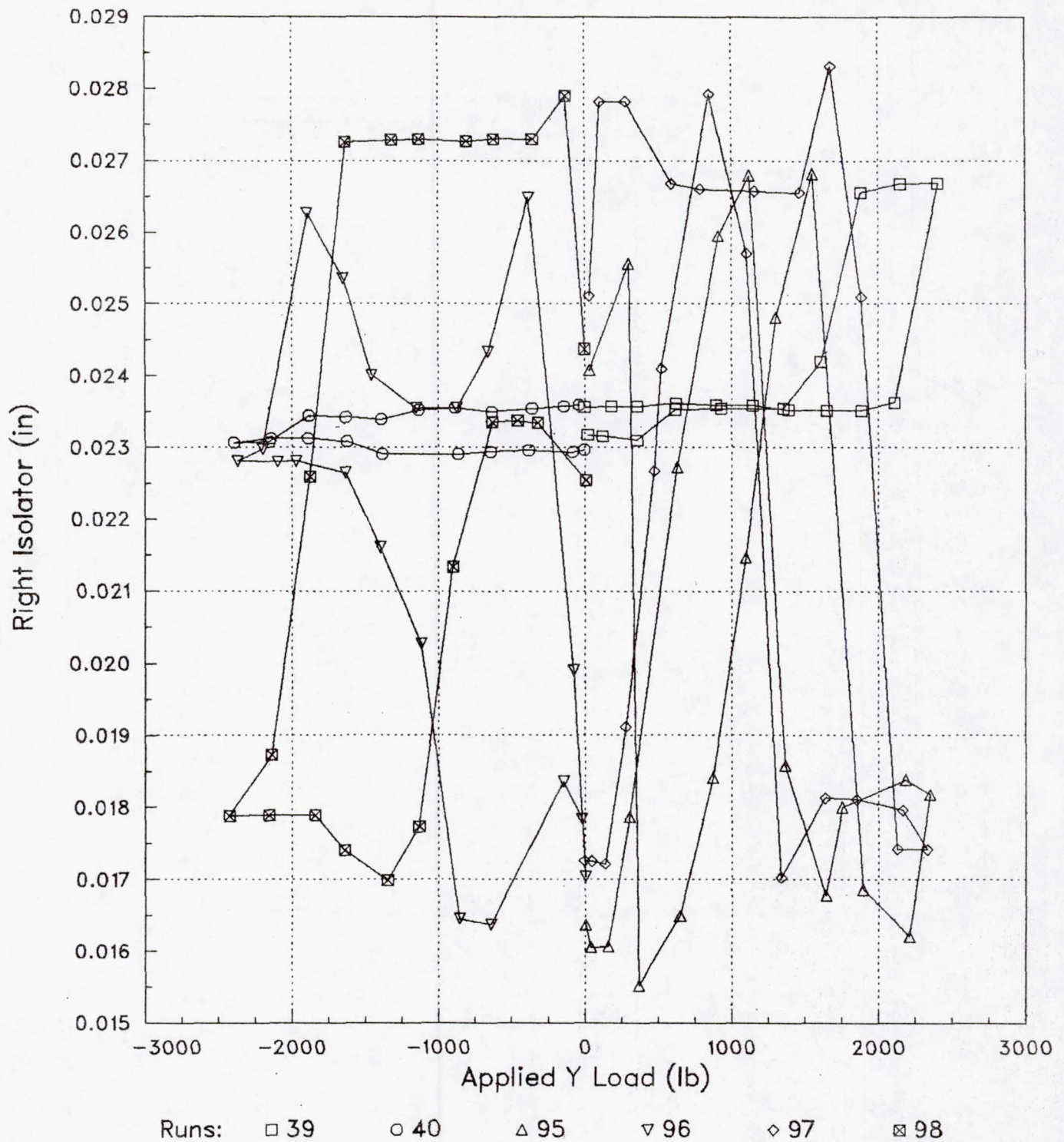
RSRA 741 1983 ROTOR CALIBRATION

Applied Y Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

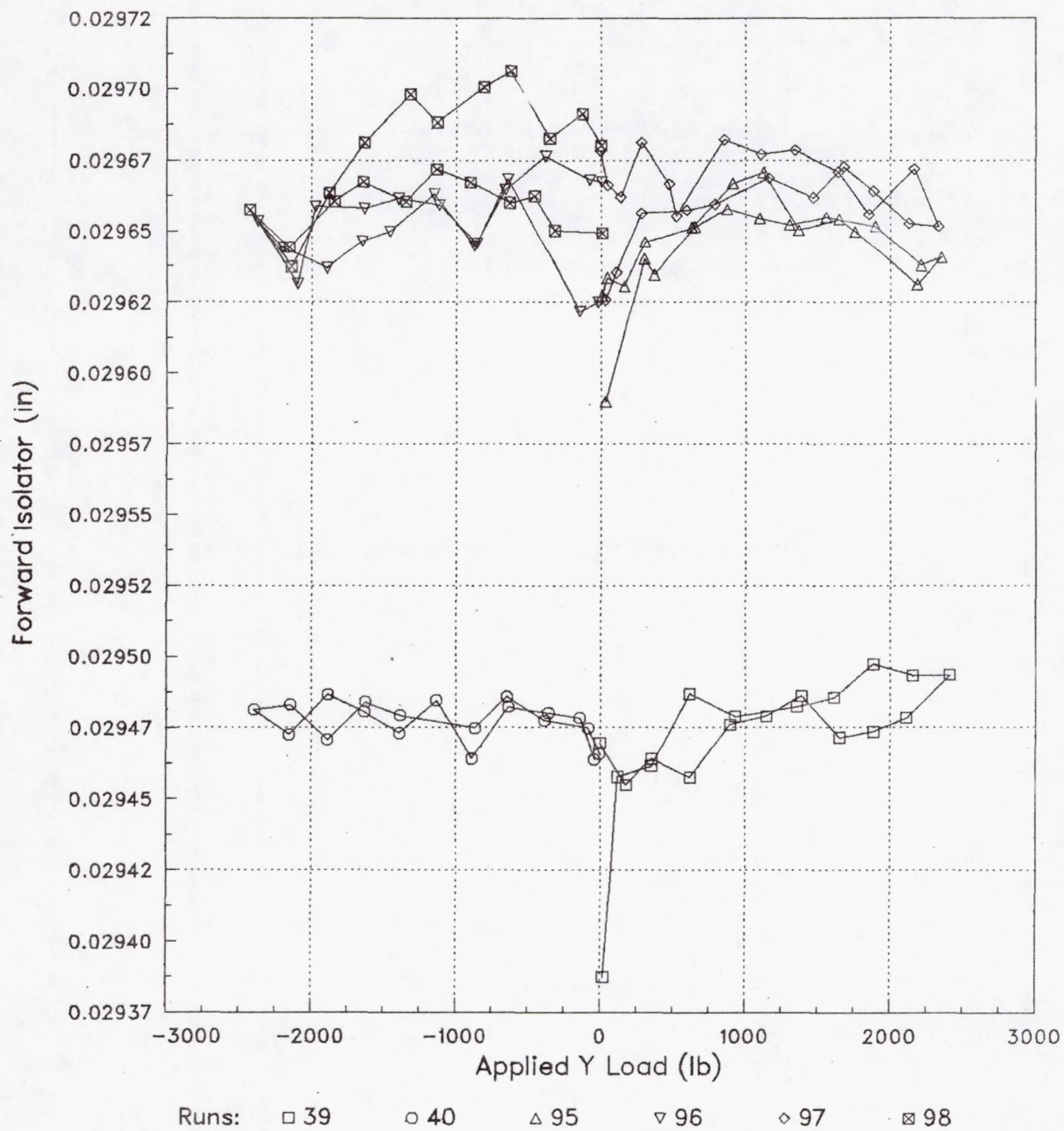
Applied Y Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

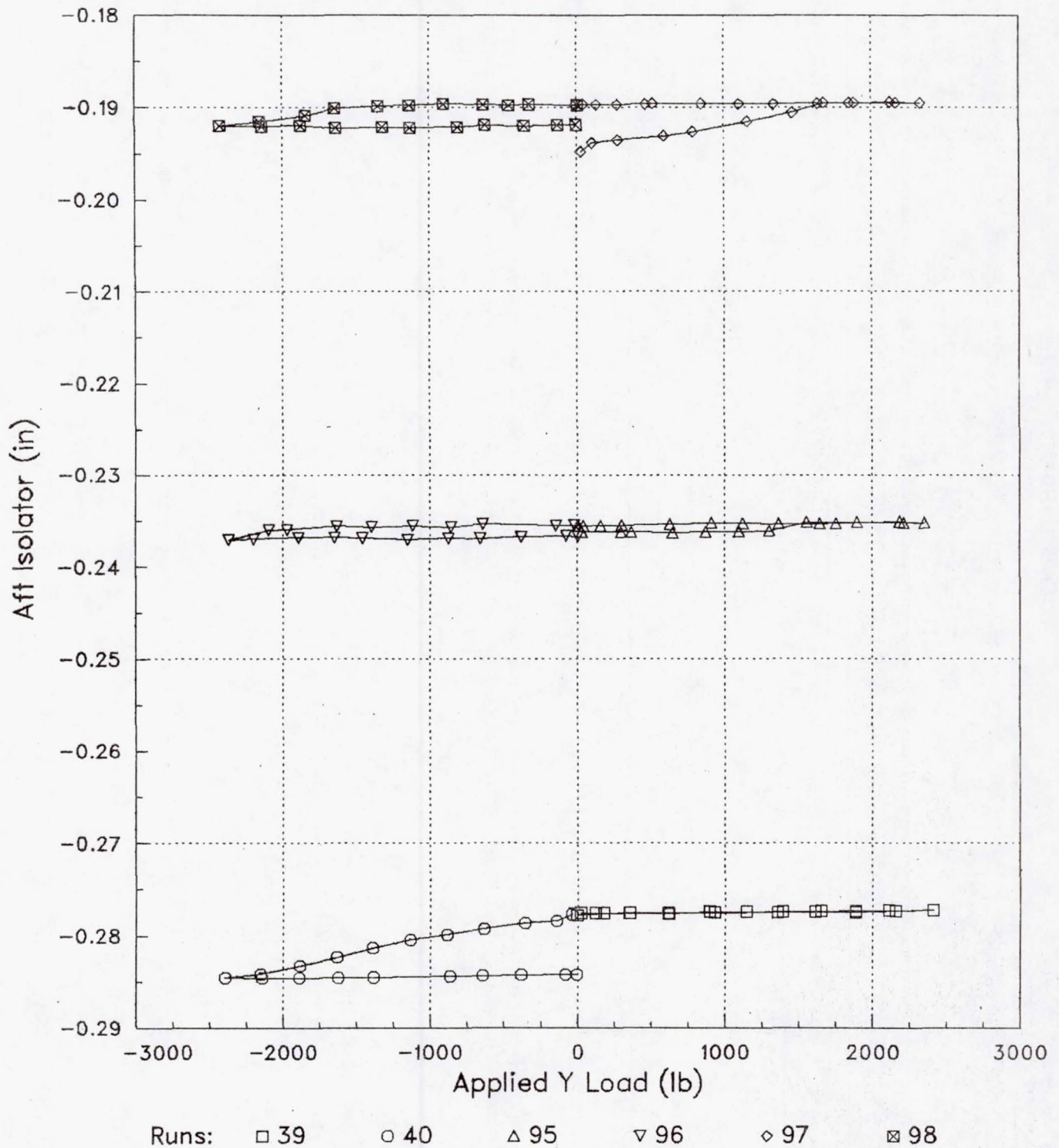
Applied Y Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

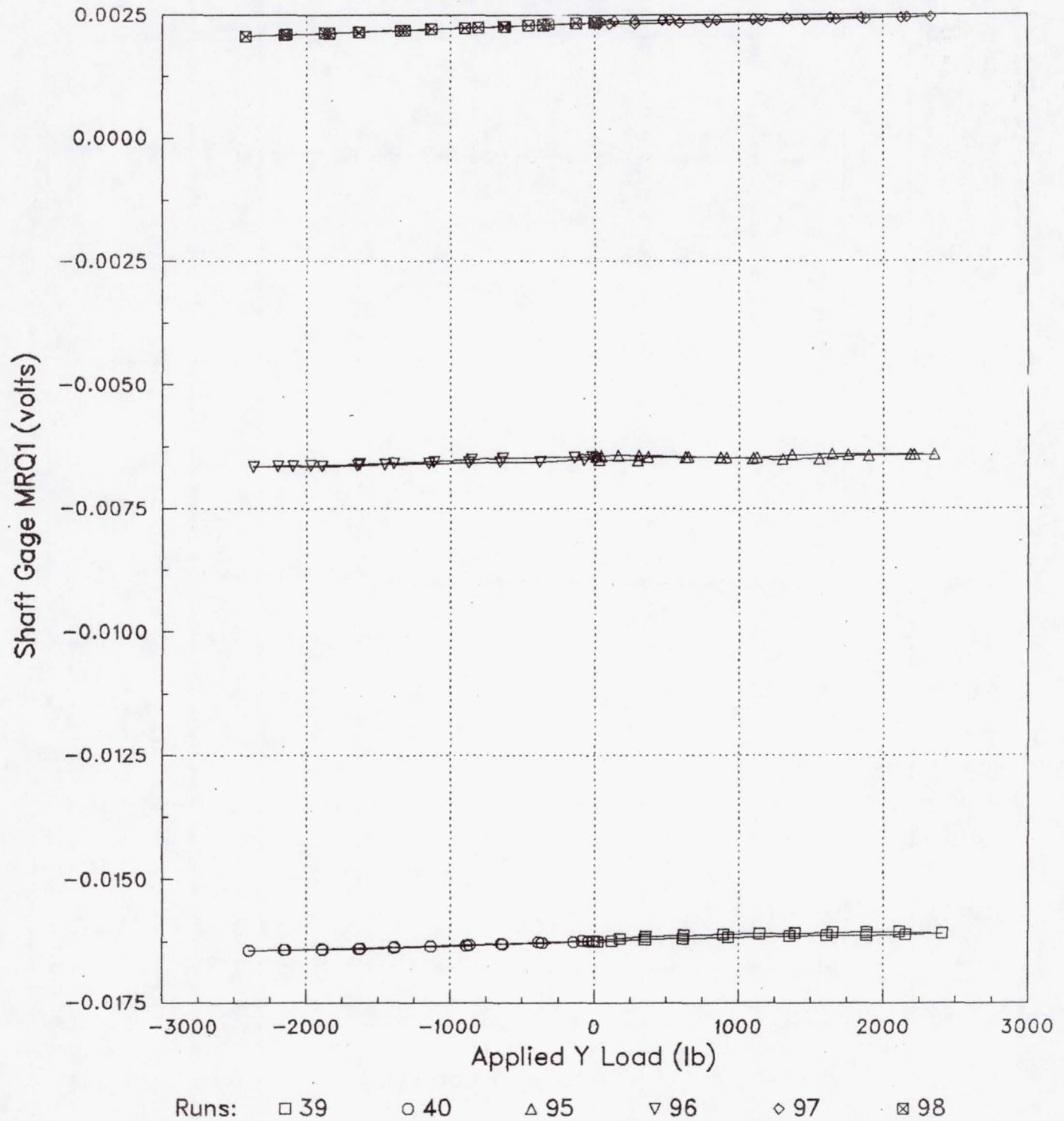
Applied Y Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

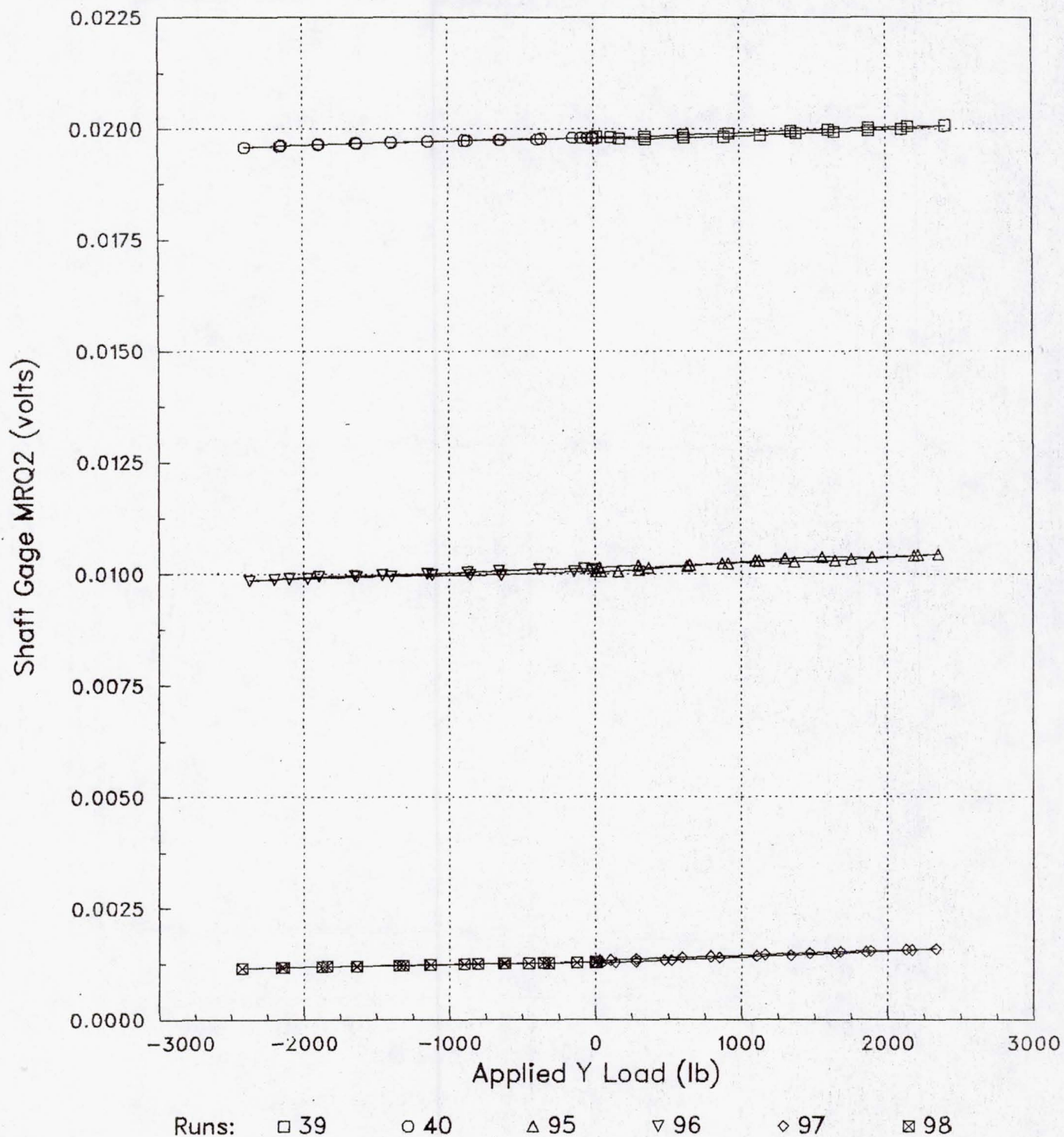
Applied Y Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

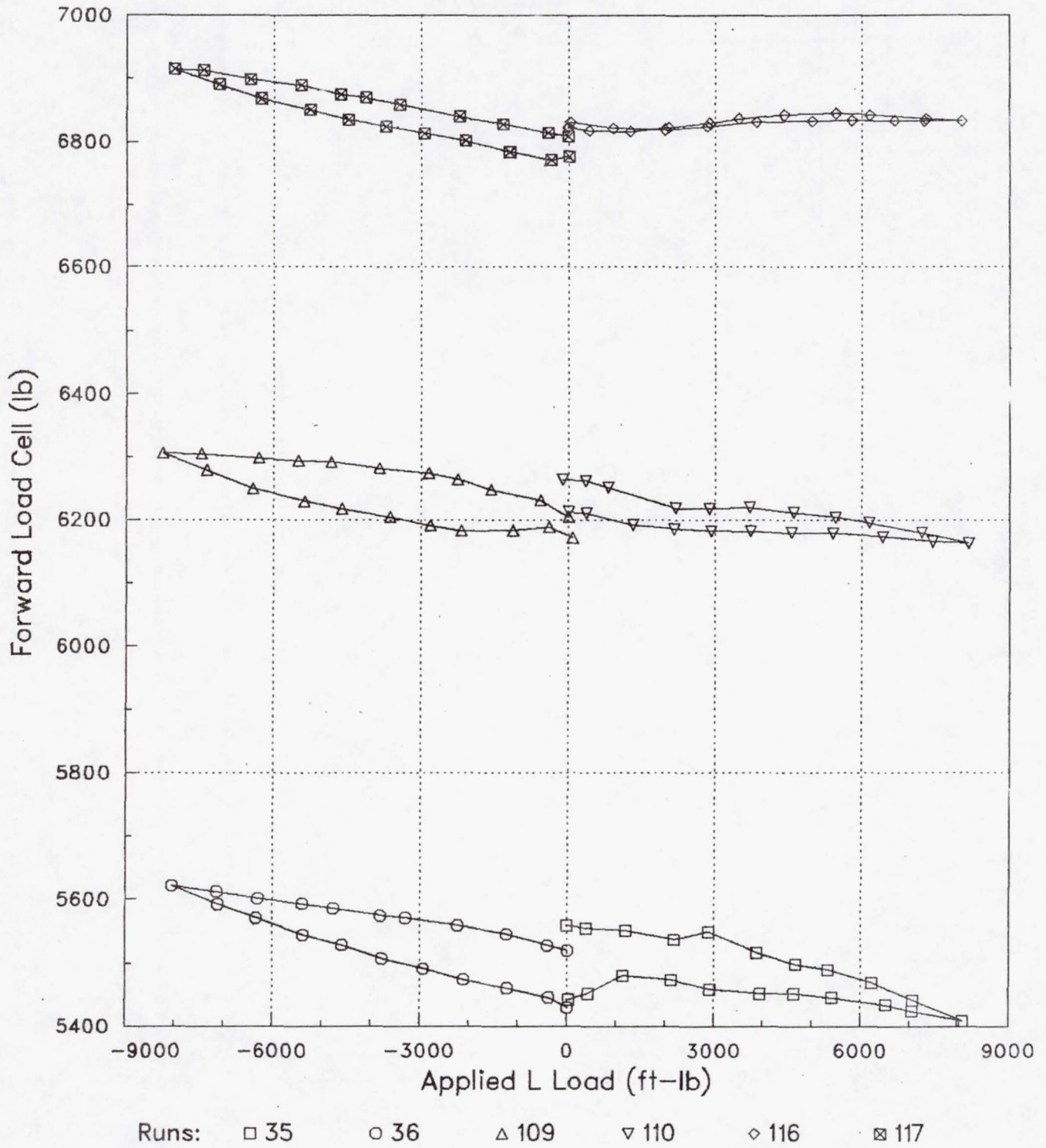
Applied Y Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

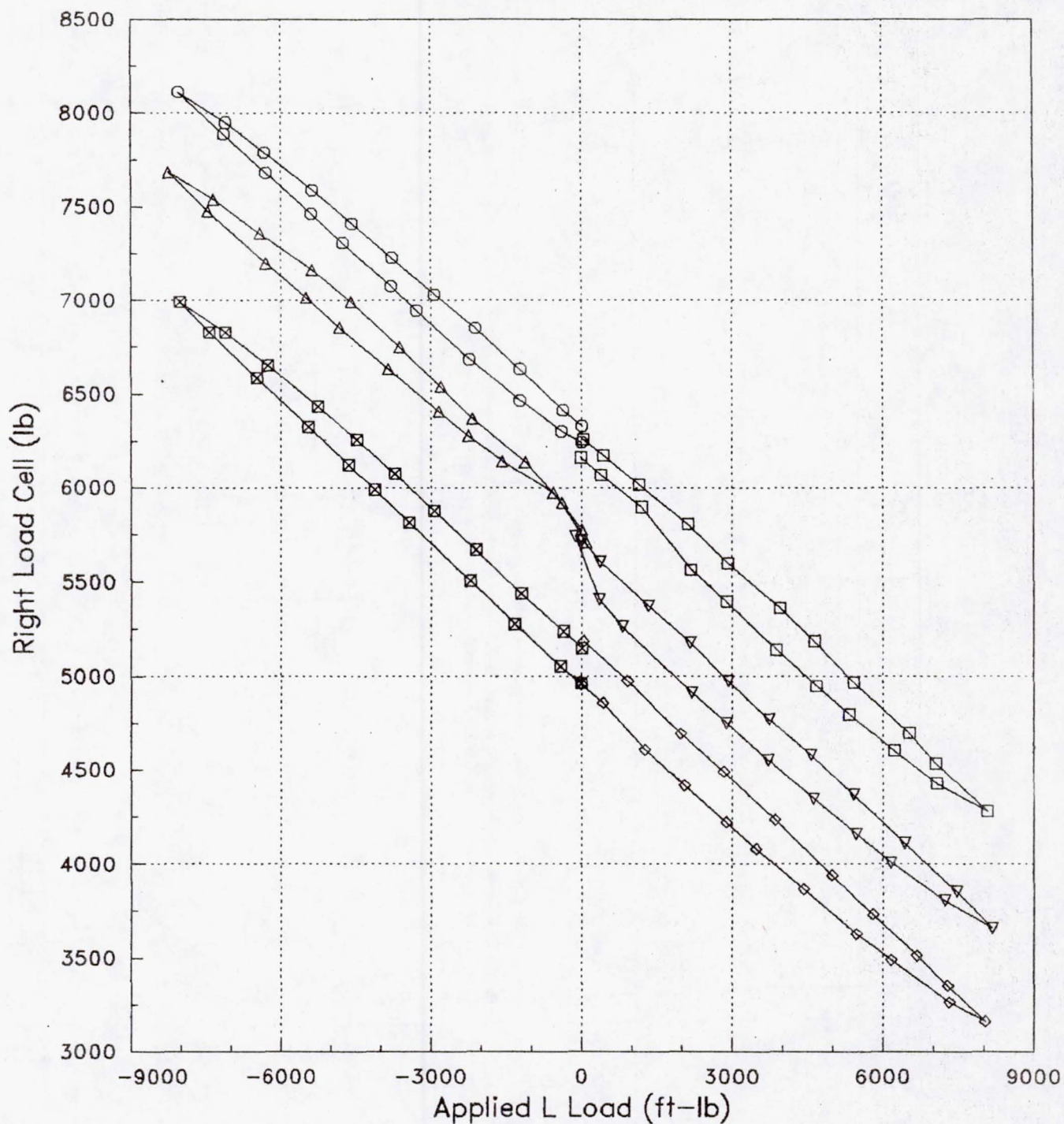
Applied L Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: 50% Z, N

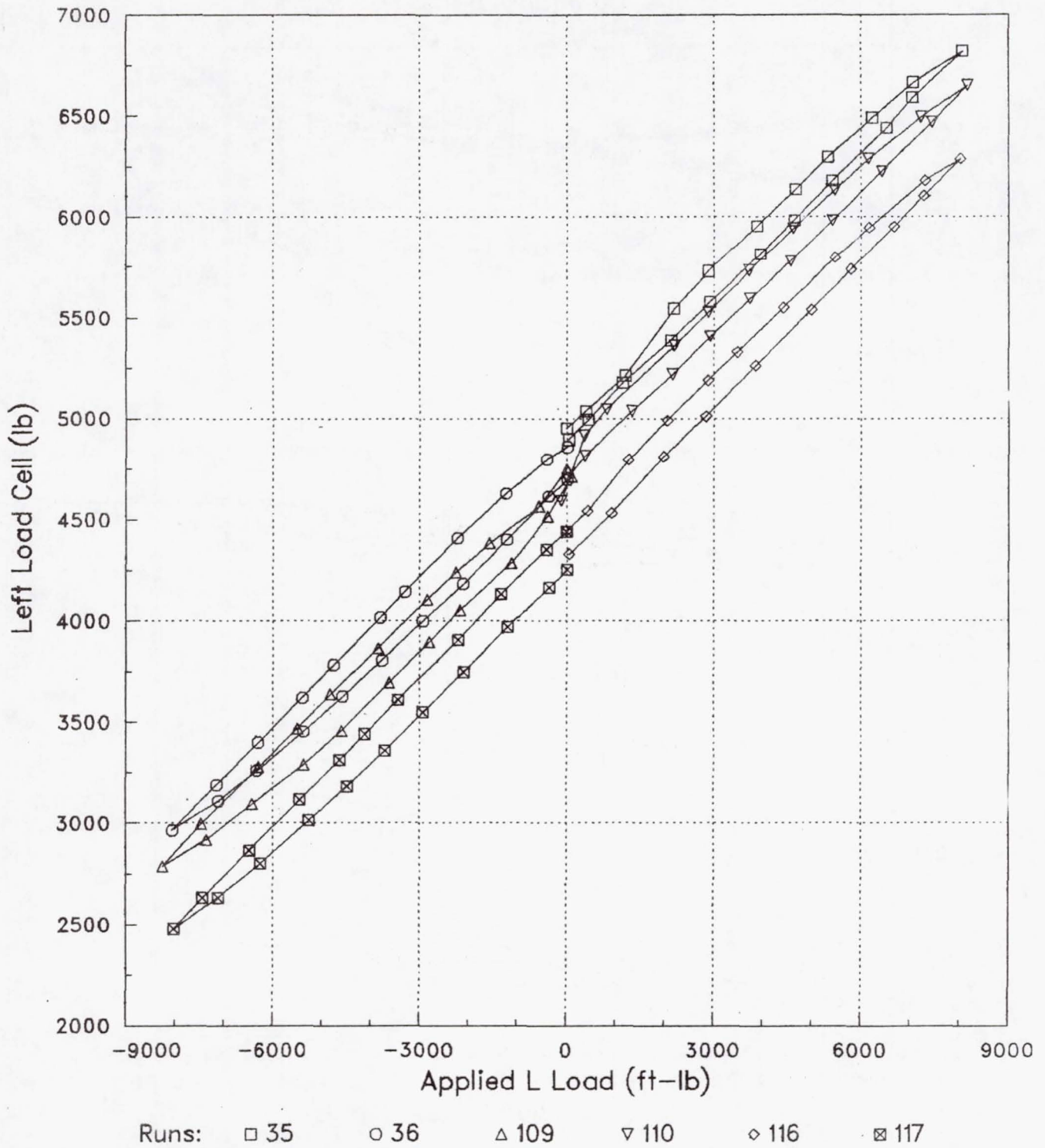


Runs: □ 35 ○ 36 △ 109 ▽ 110 ◇ 116 ⊠ 117

RSRA 741 1983 ROTOR CALIBRATION

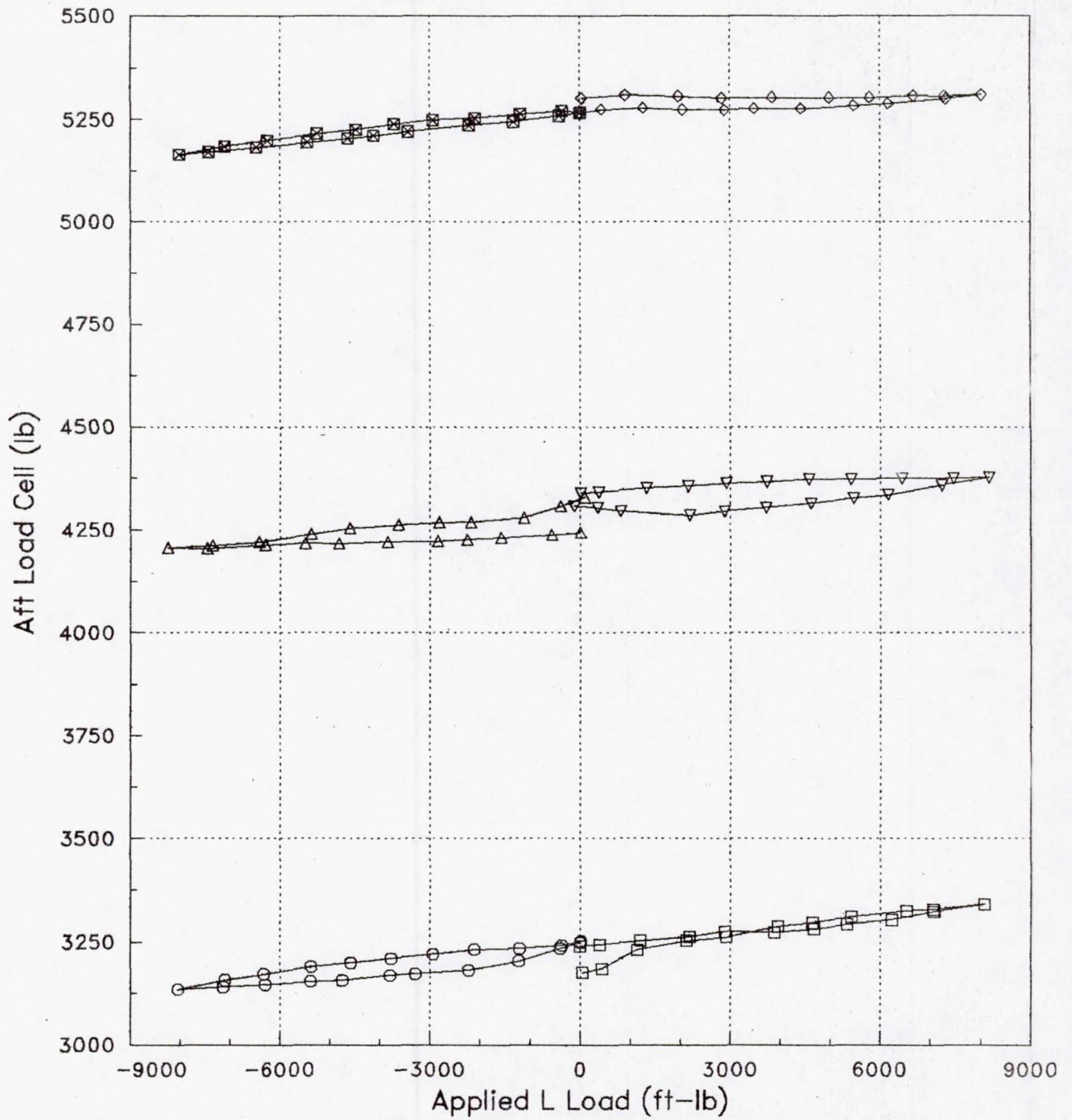
Applied L Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

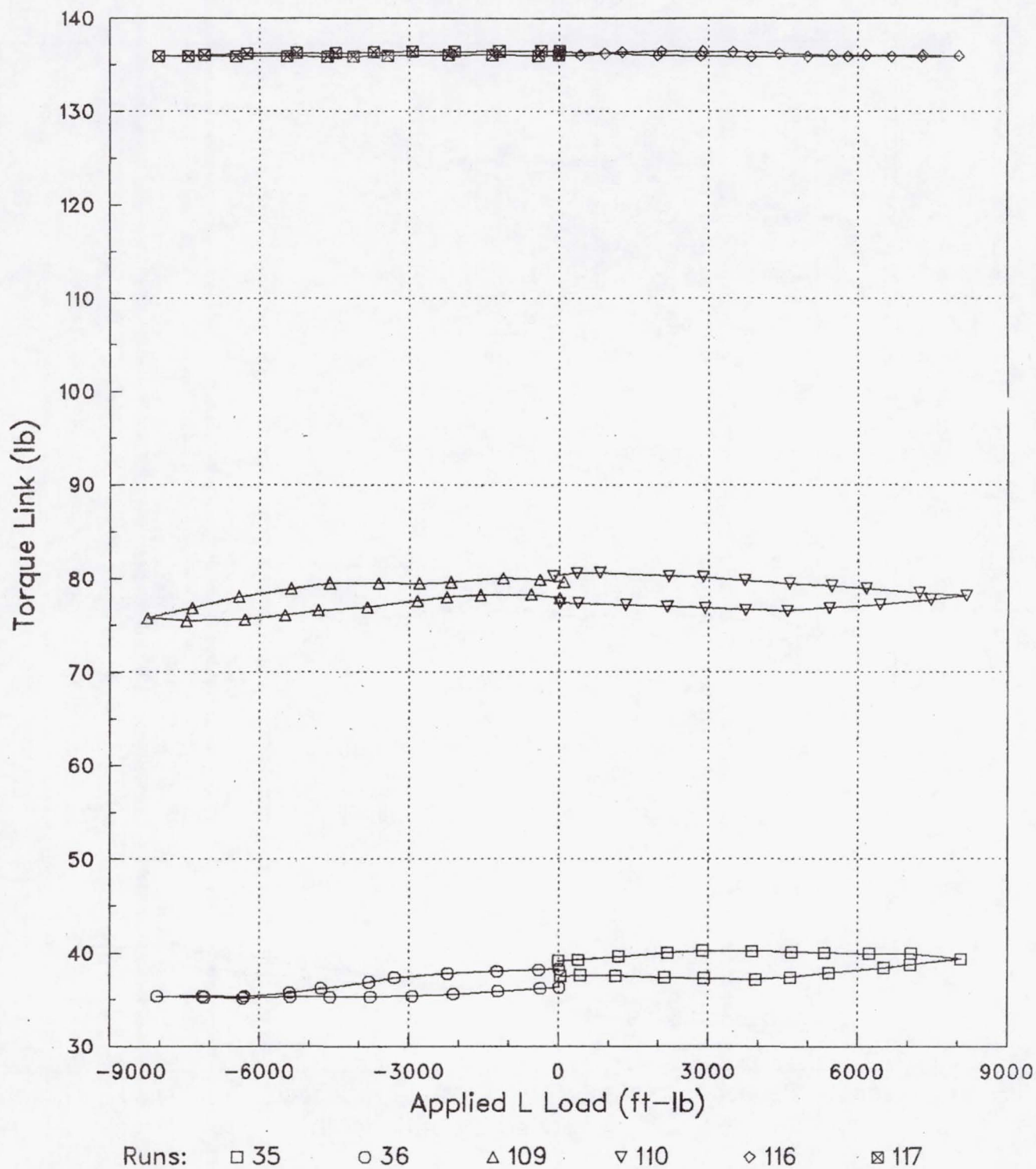
Applied L Load
Constant Loads: 50% Z, N



Runs: □ 35 ○ 36 △ 109 ▽ 110 ◇ 116 ⊠ 117

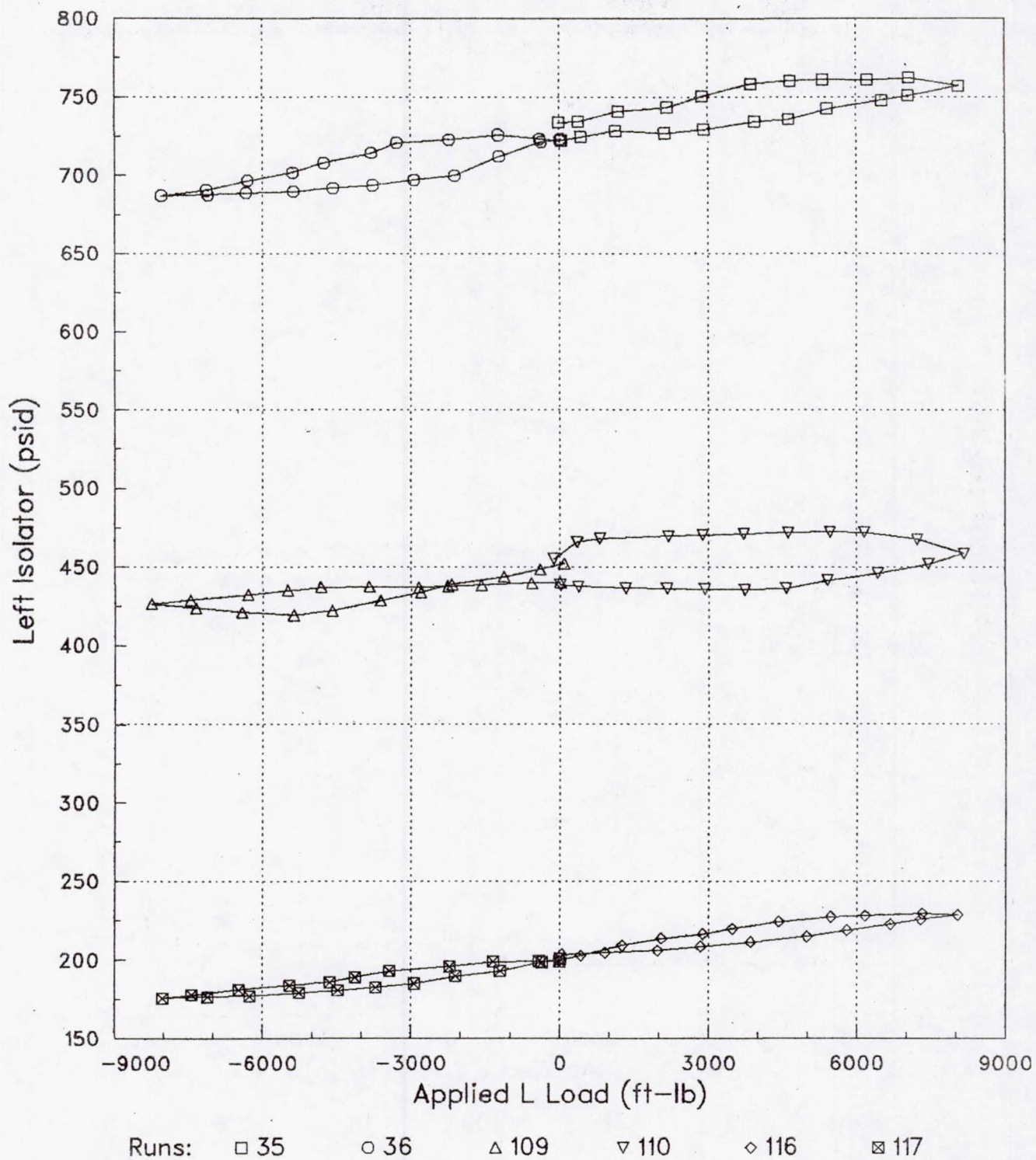
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

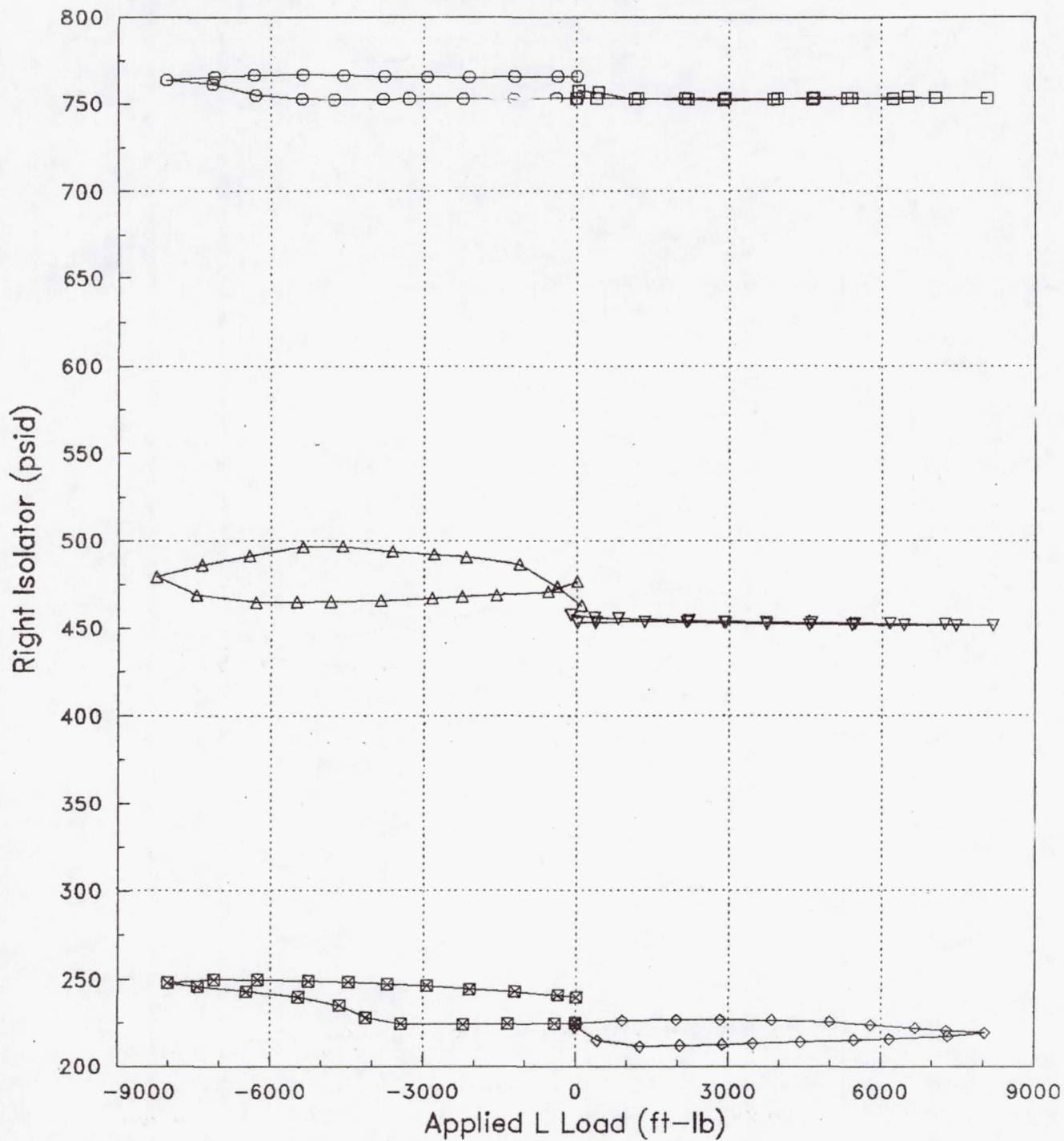
Applied L Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

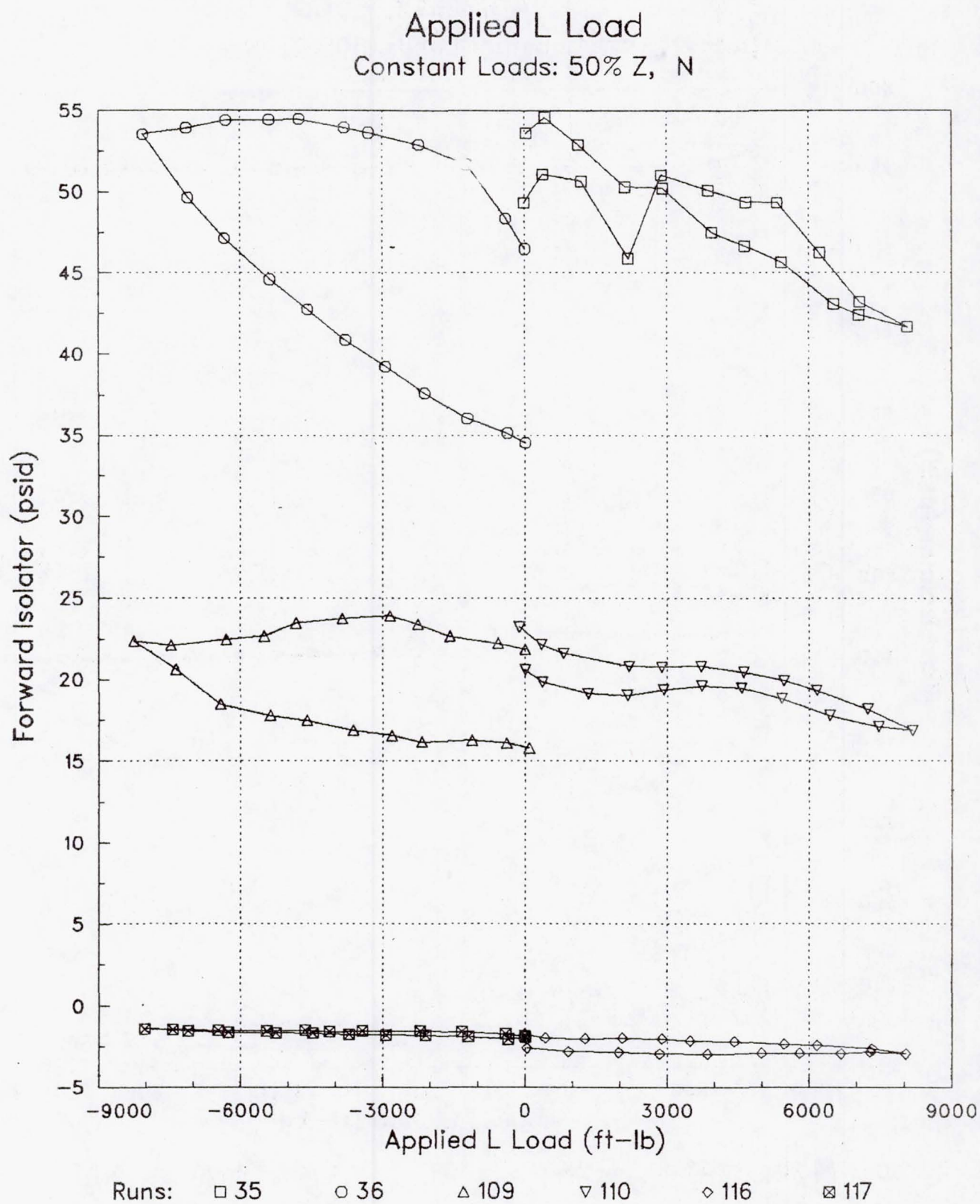
Applied L Load

Constant Loads: 50% Z, N



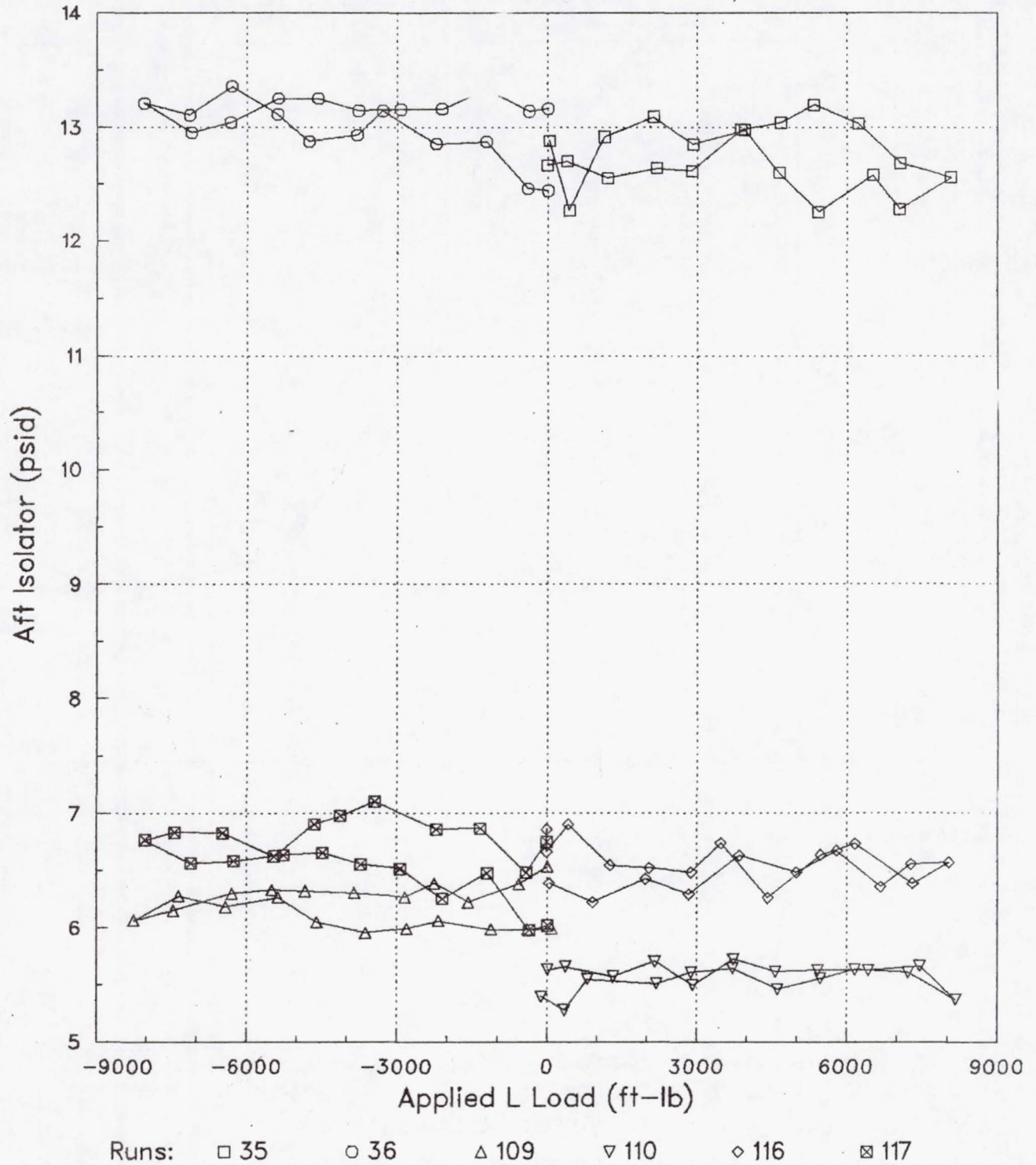
Runs: □ 35 ○ 36 △ 109 ▽ 110 ◇ 116 ⊠ 117

RSRA 741 1983 ROTOR CALIBRATION



RSRA 741 1983 ROTOR CALIBRATION

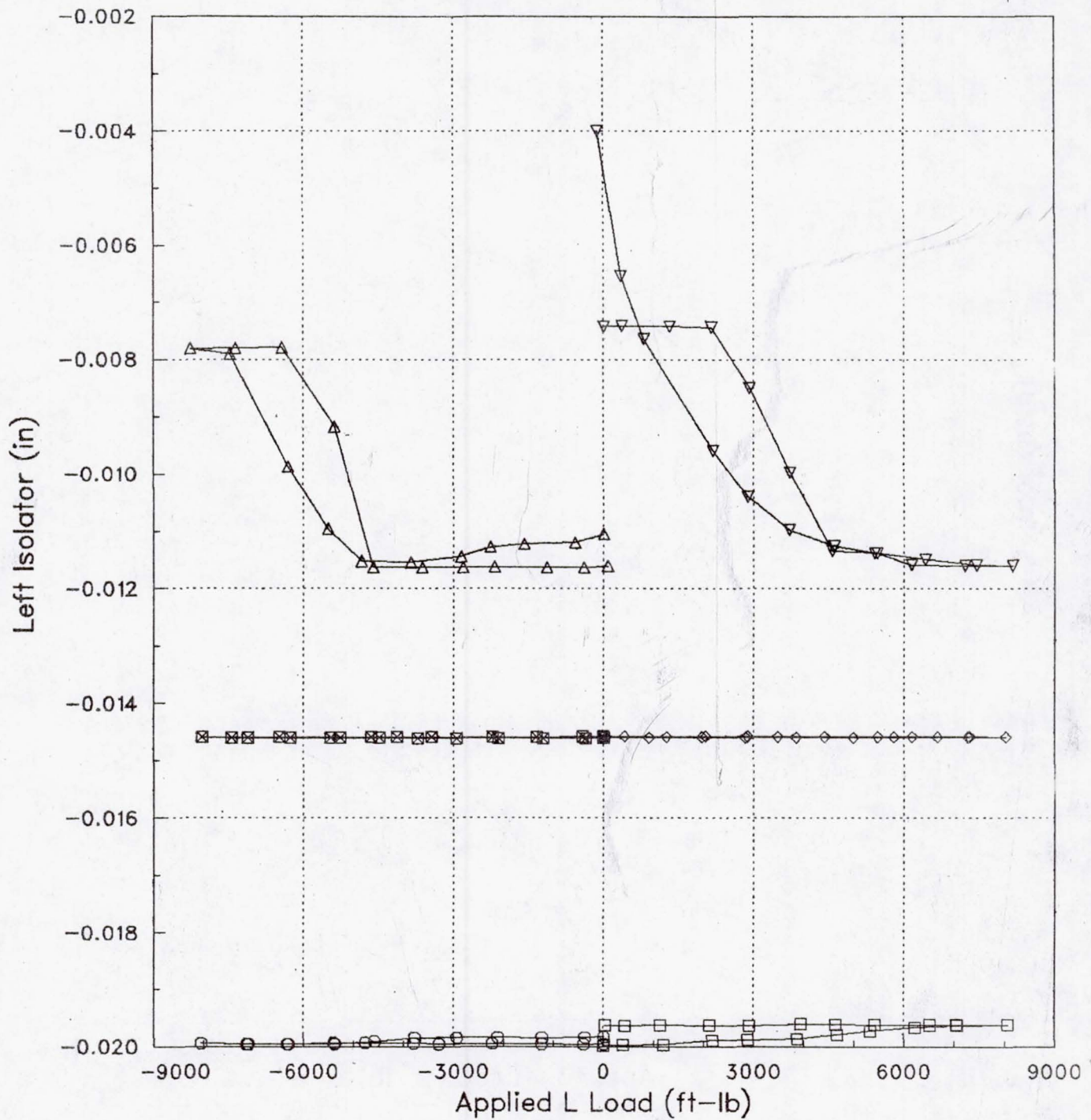
Applied L Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

Applied L Load

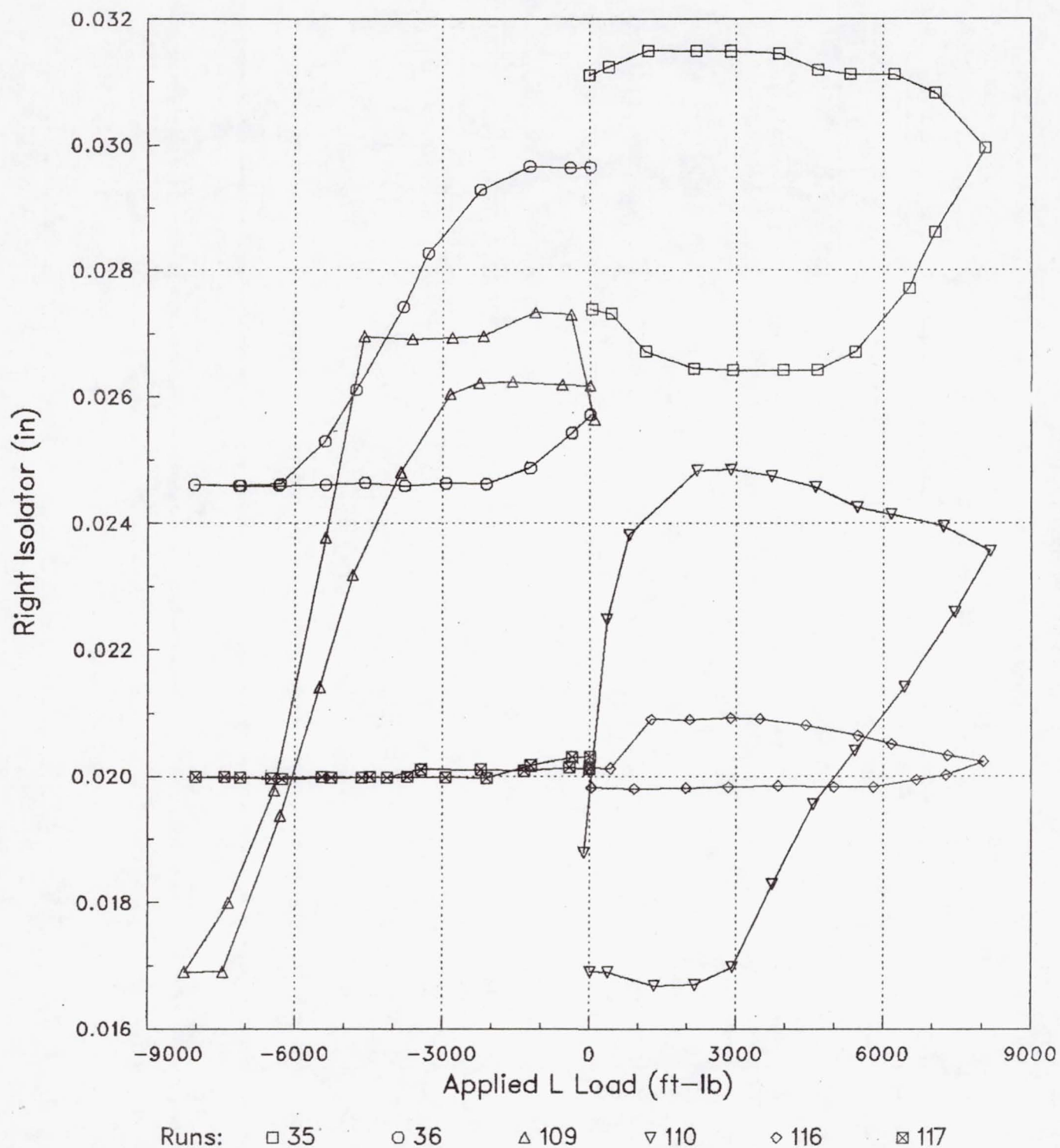
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

Applied L Load

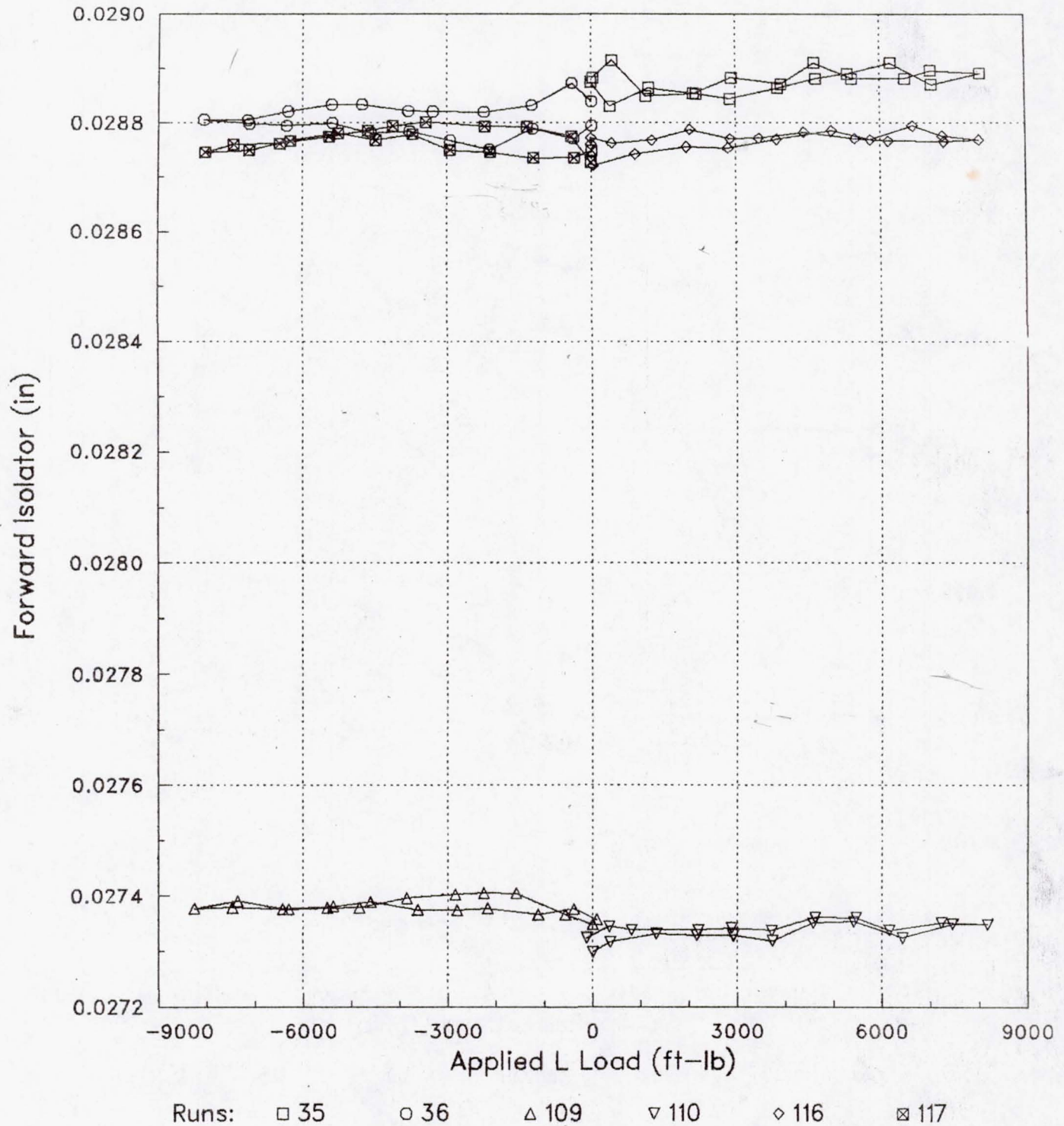
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

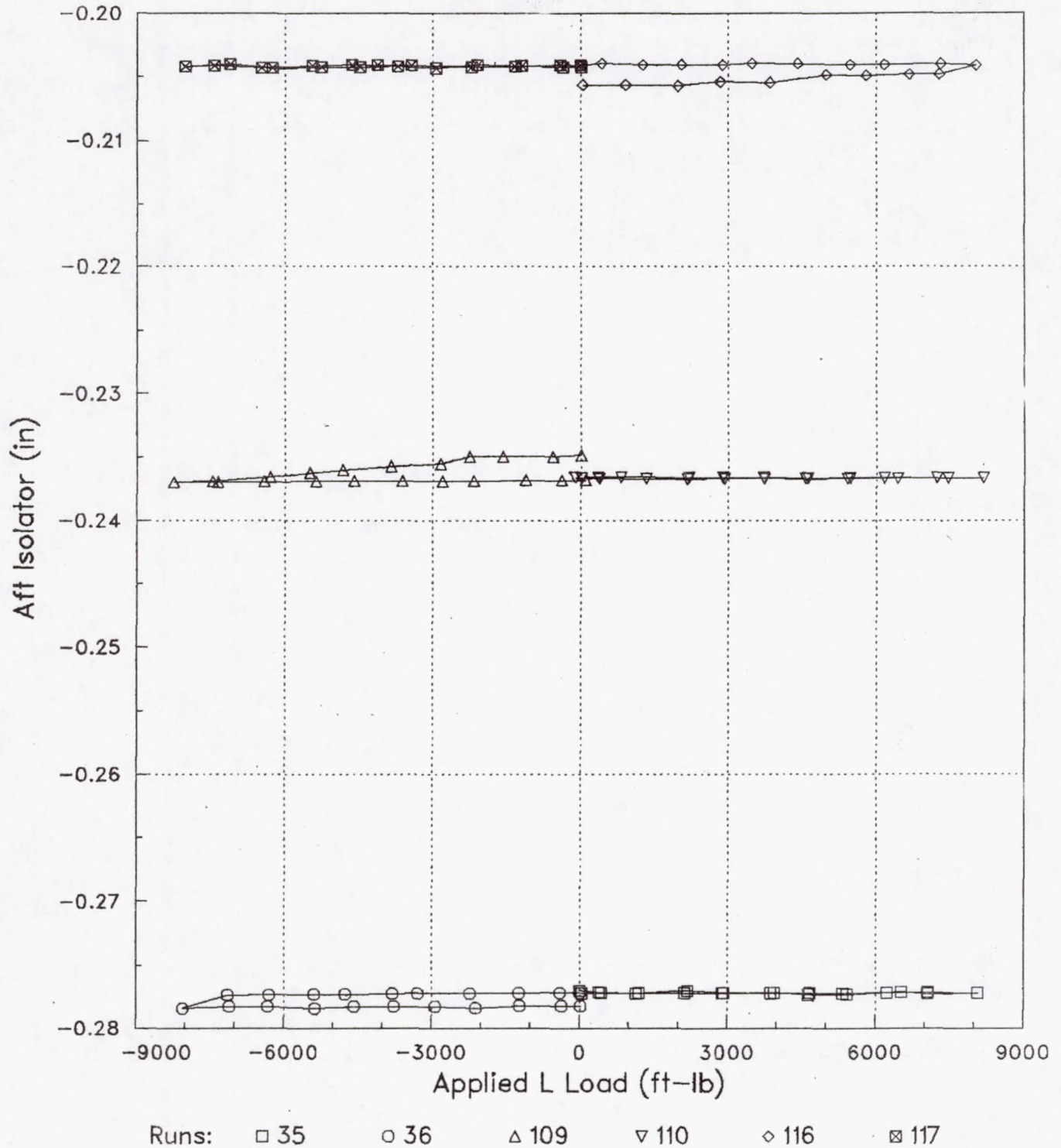
Applied L Load

Constant Loads: 50% Z, N



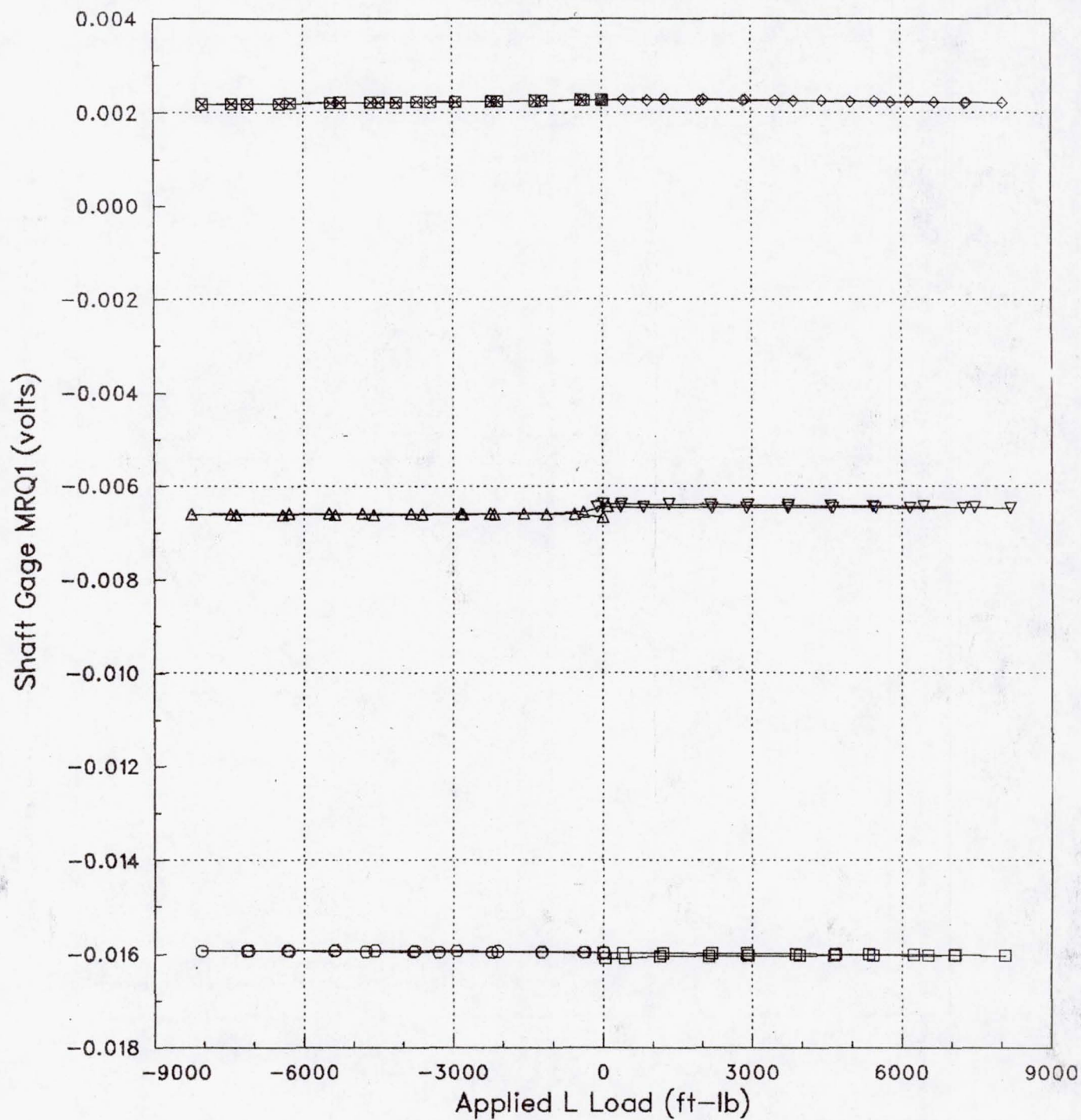
RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

Applied L Load
Constant Loads: 50% Z, N

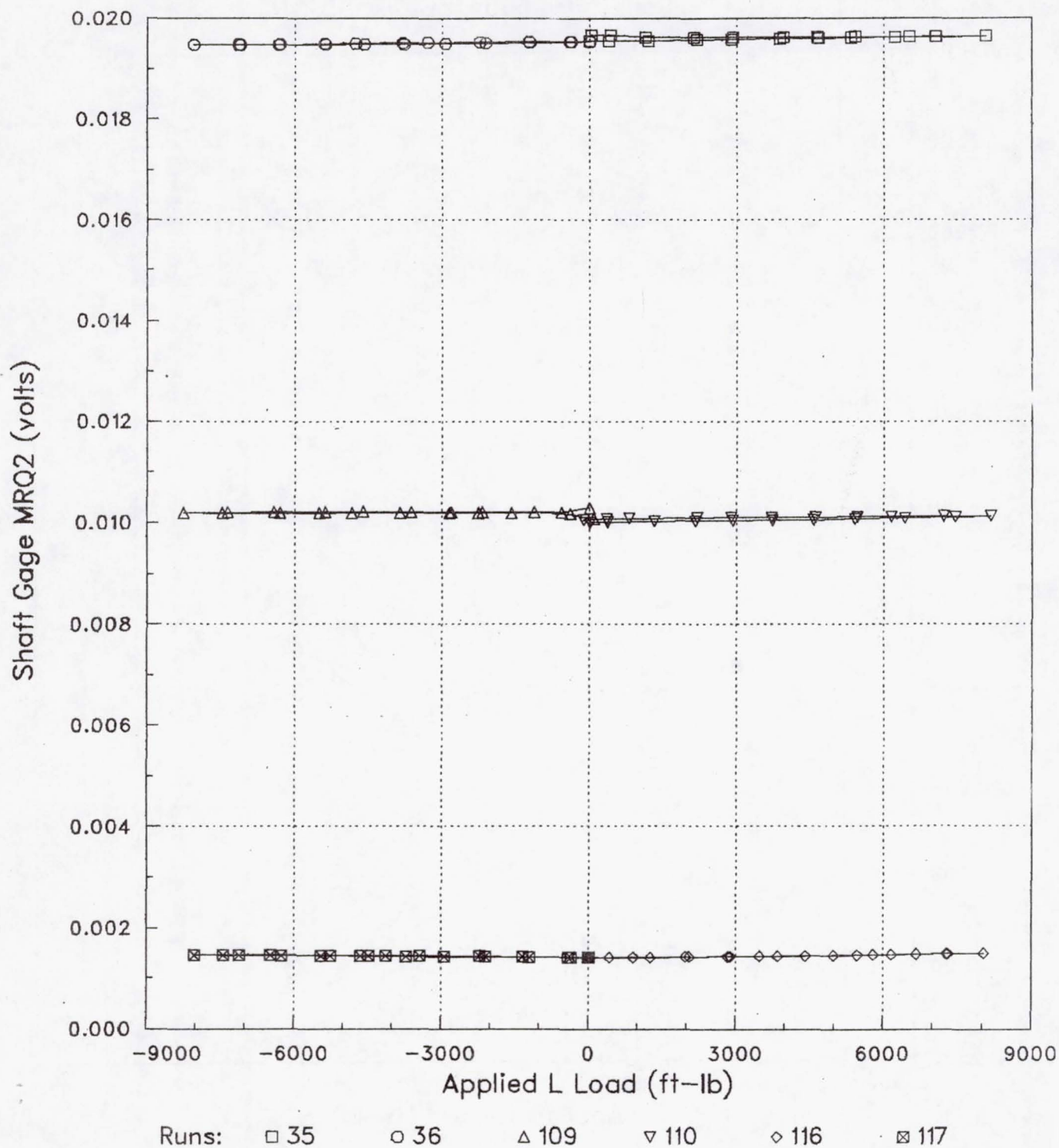


Runs: □ 35 ○ 36 △ 109 ▽ 110 ◇ 116 ⊠ 117

RSRA 741 1983 ROTOR CALIBRATION

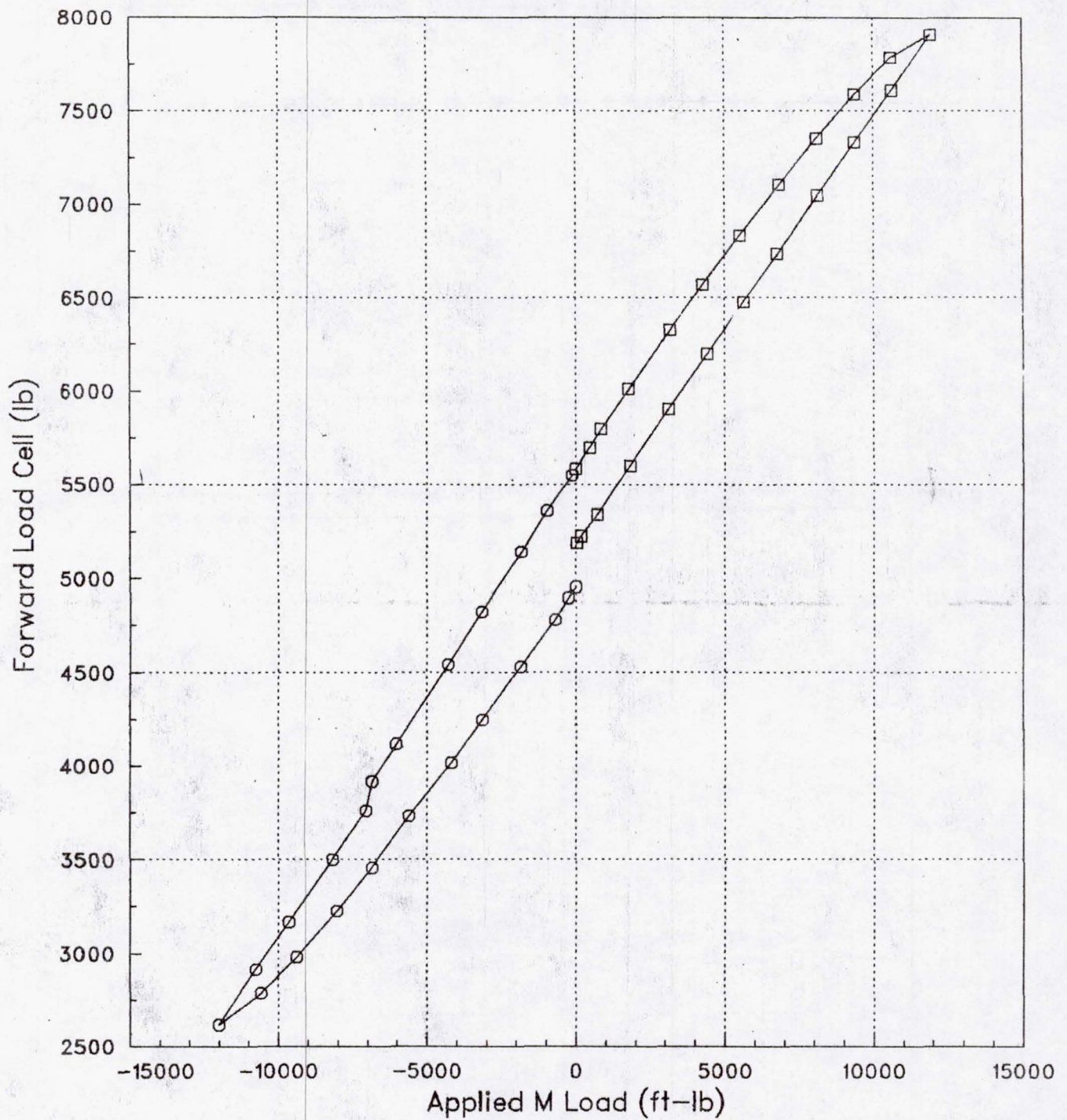
Applied L Load

Constant Loads: 50% Z, N



RSRA 741 1983 ROTOR CALIBRATION

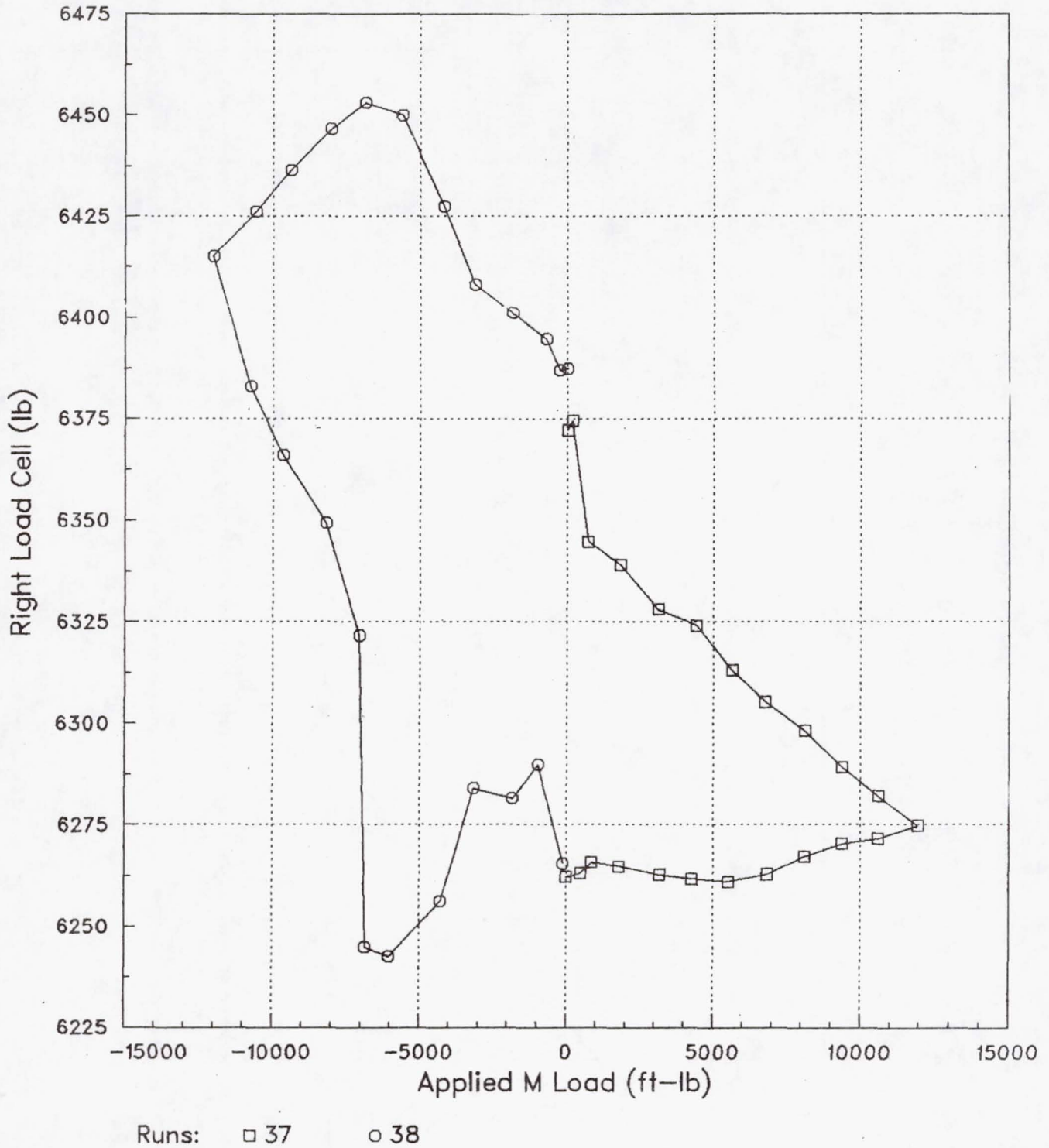
Applied M Load
Constant Loads: 50% Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

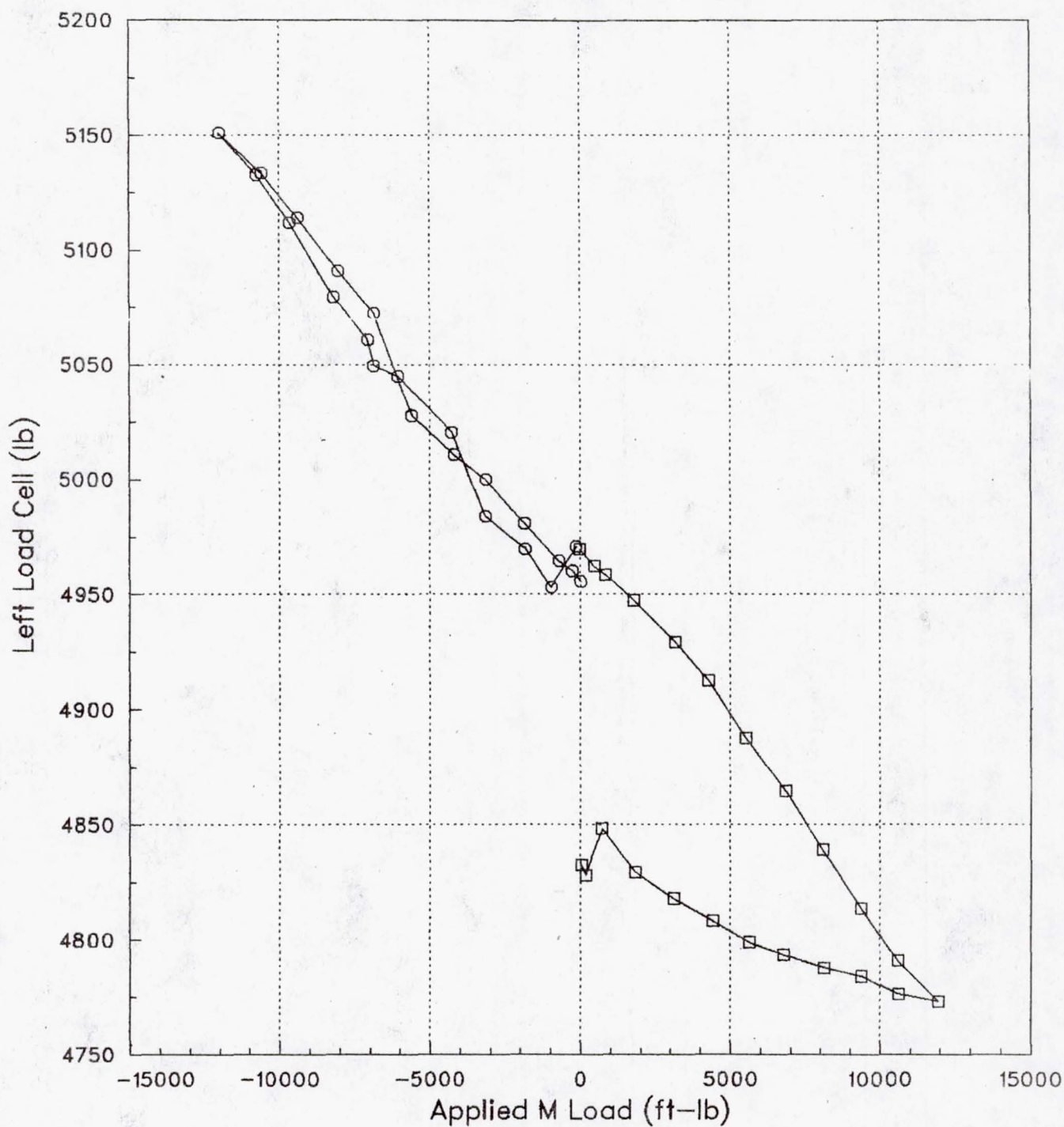
Applied M Load

Constant Loads: 50% Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

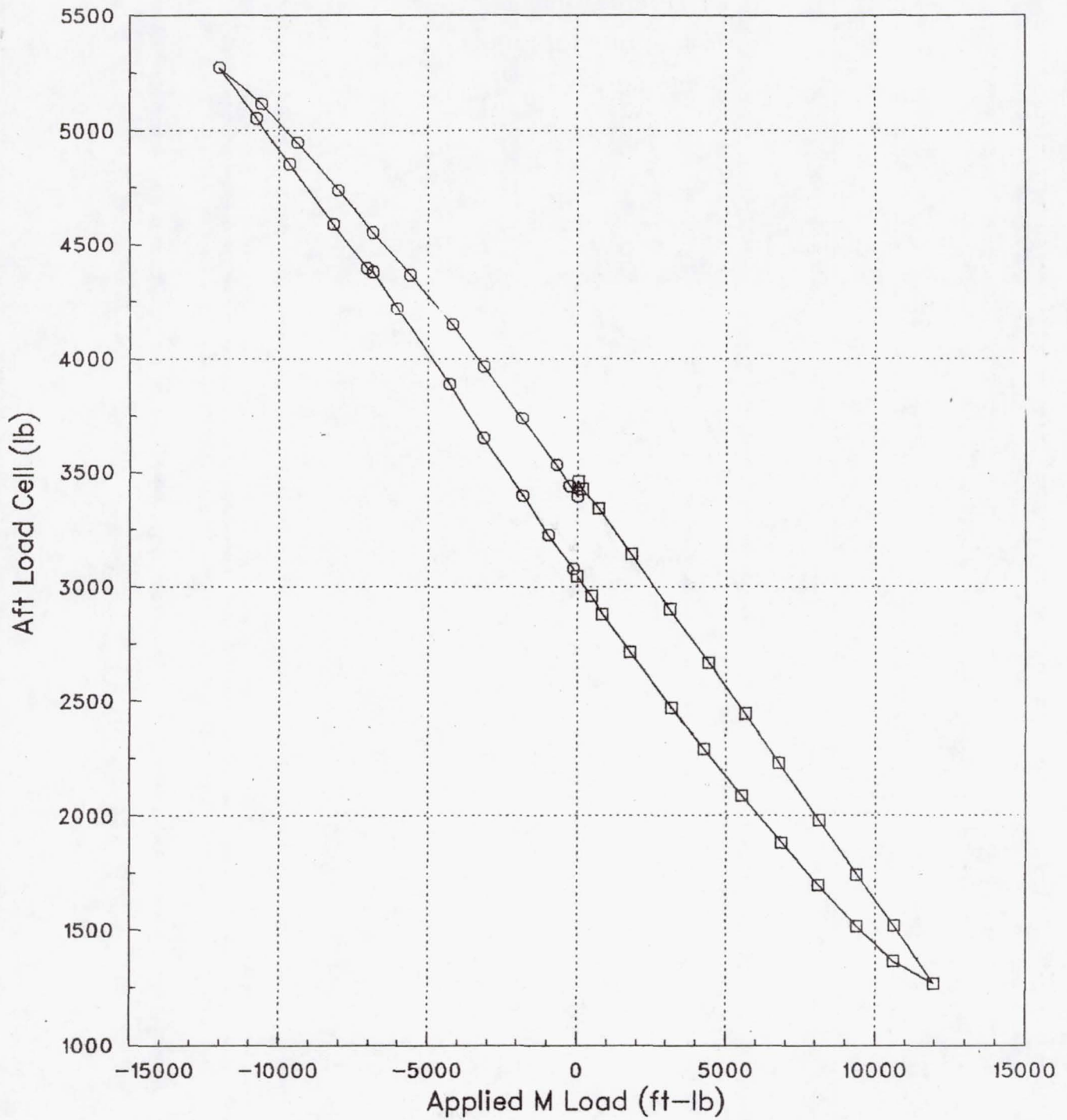
Applied M Load
Constant Loads: 50% Z, 85% N



Runs: □ 37 ○ 38

RSRA 741 1983 ROTOR CALIBRATION

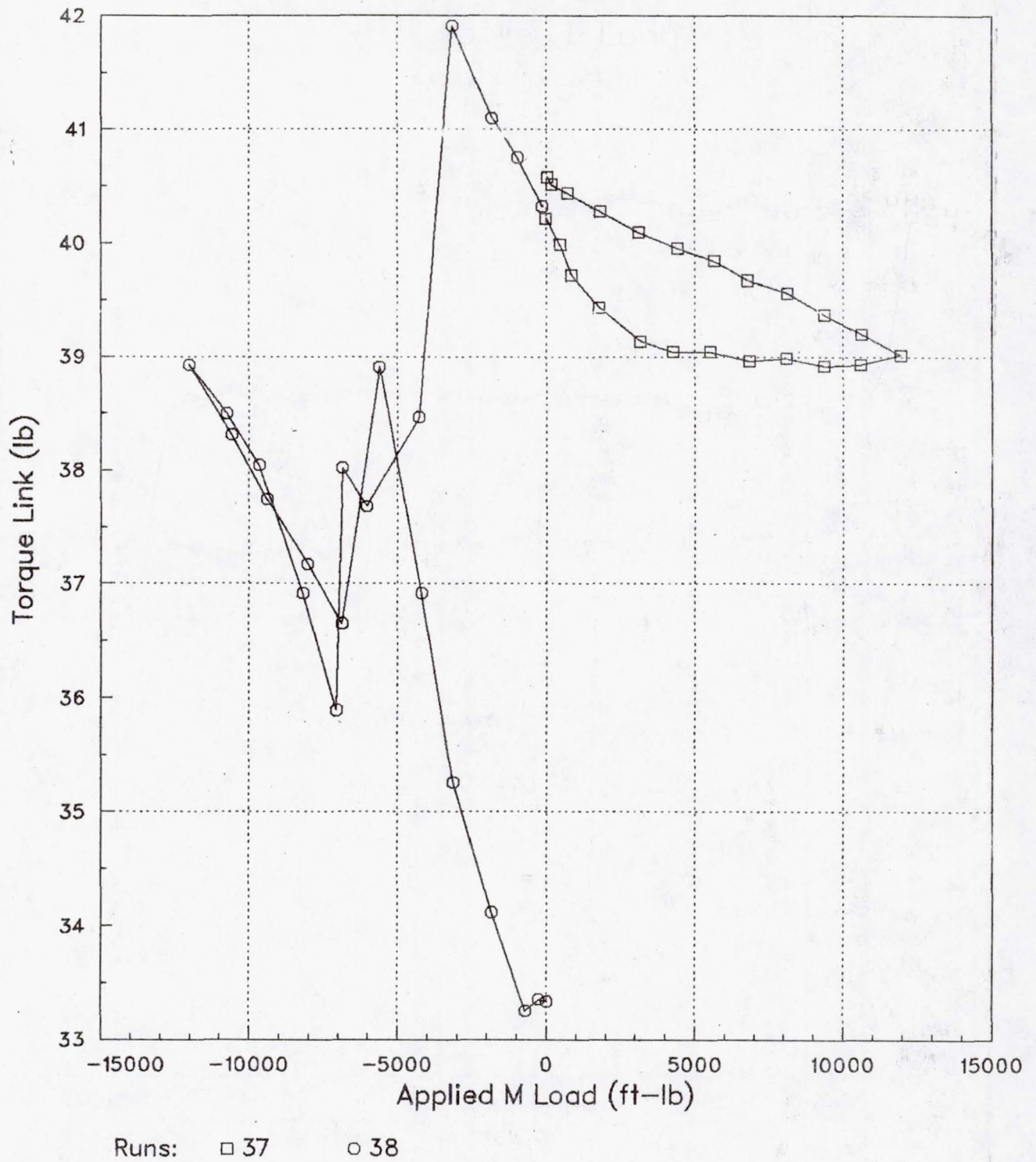
Applied M Load
Constant Loads: 50% Z, 85% N



Runs: □ 37 ○ 38

RSKA 741 1983 ROTOR CALIBRATION

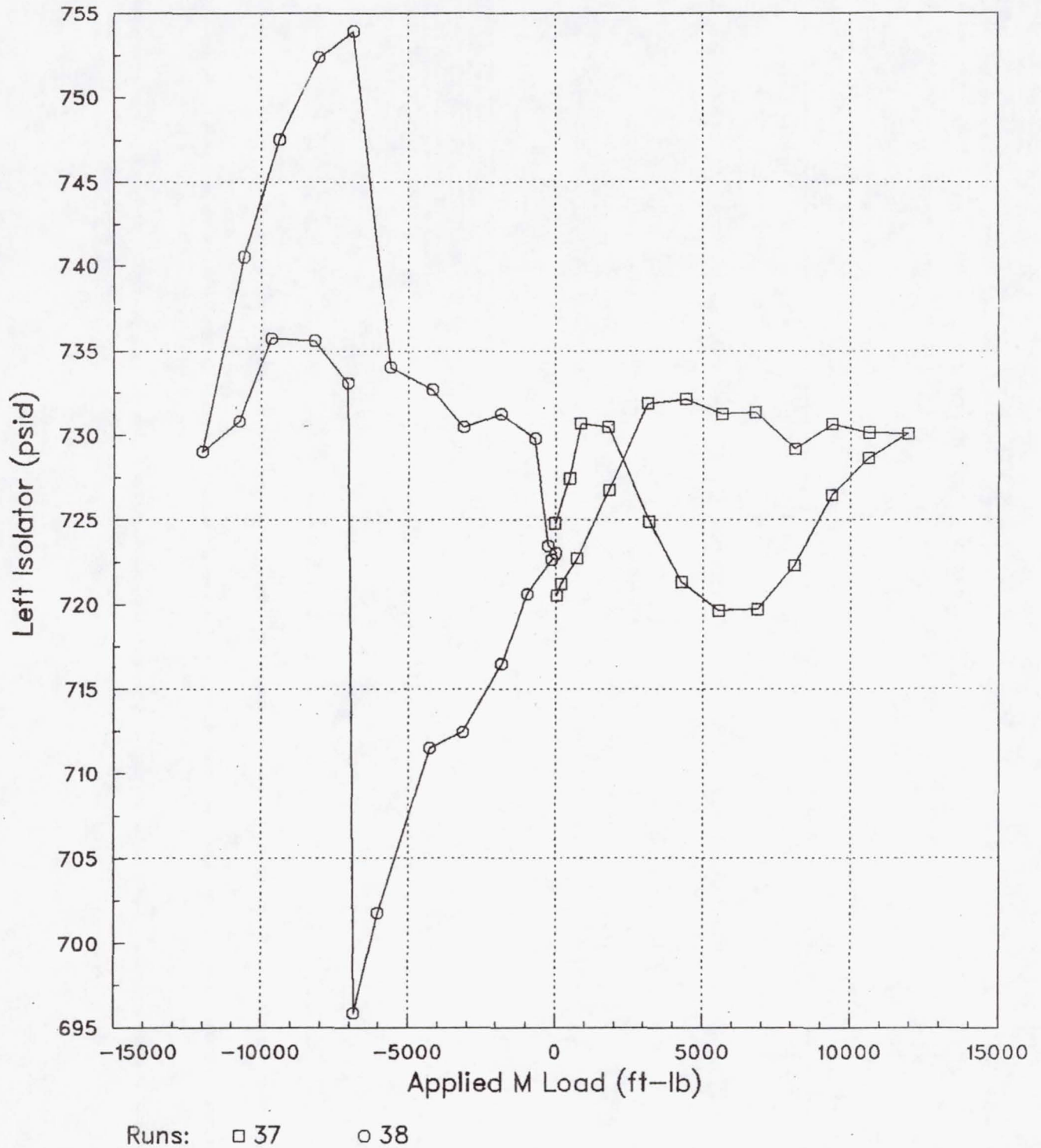
Applied M Load
Constant Loads: 50% Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

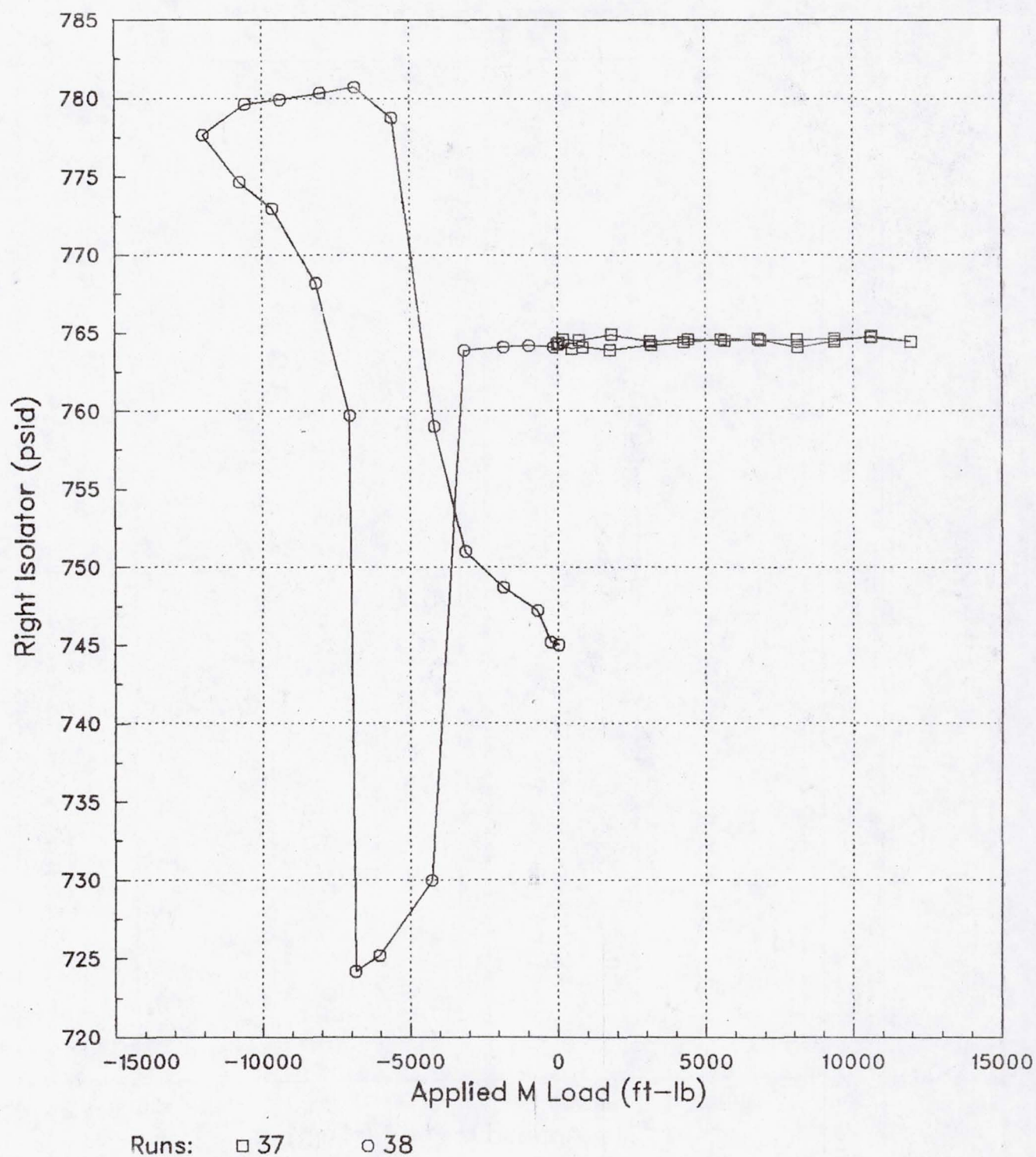
Constant Loads: 50% Z, 85% N



RSNA 741 1983 ROTOR CALIBRATION

Applied M Load

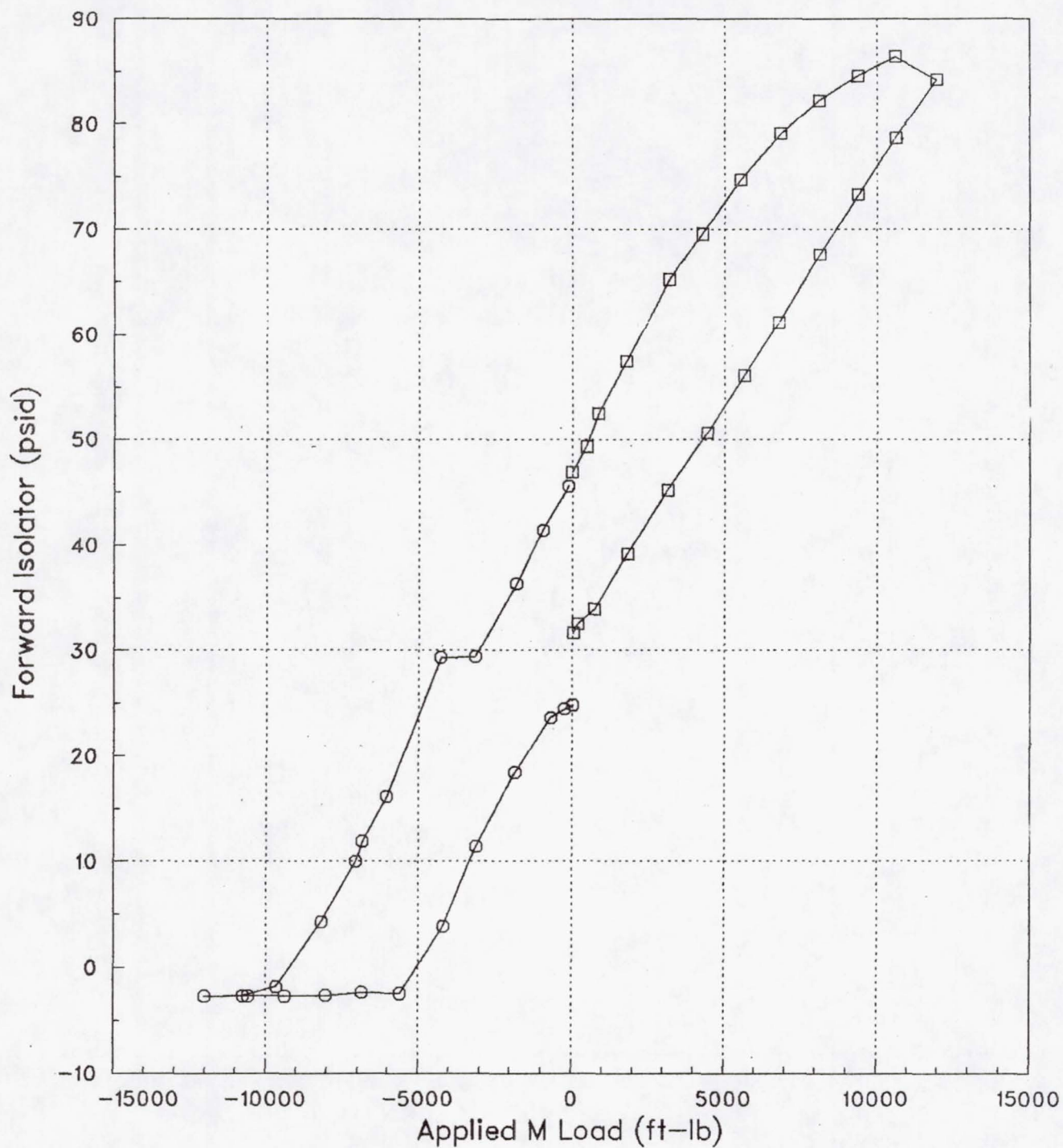
Constant Loads: 50% Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

Constant Loads: 50% Z, 85% N

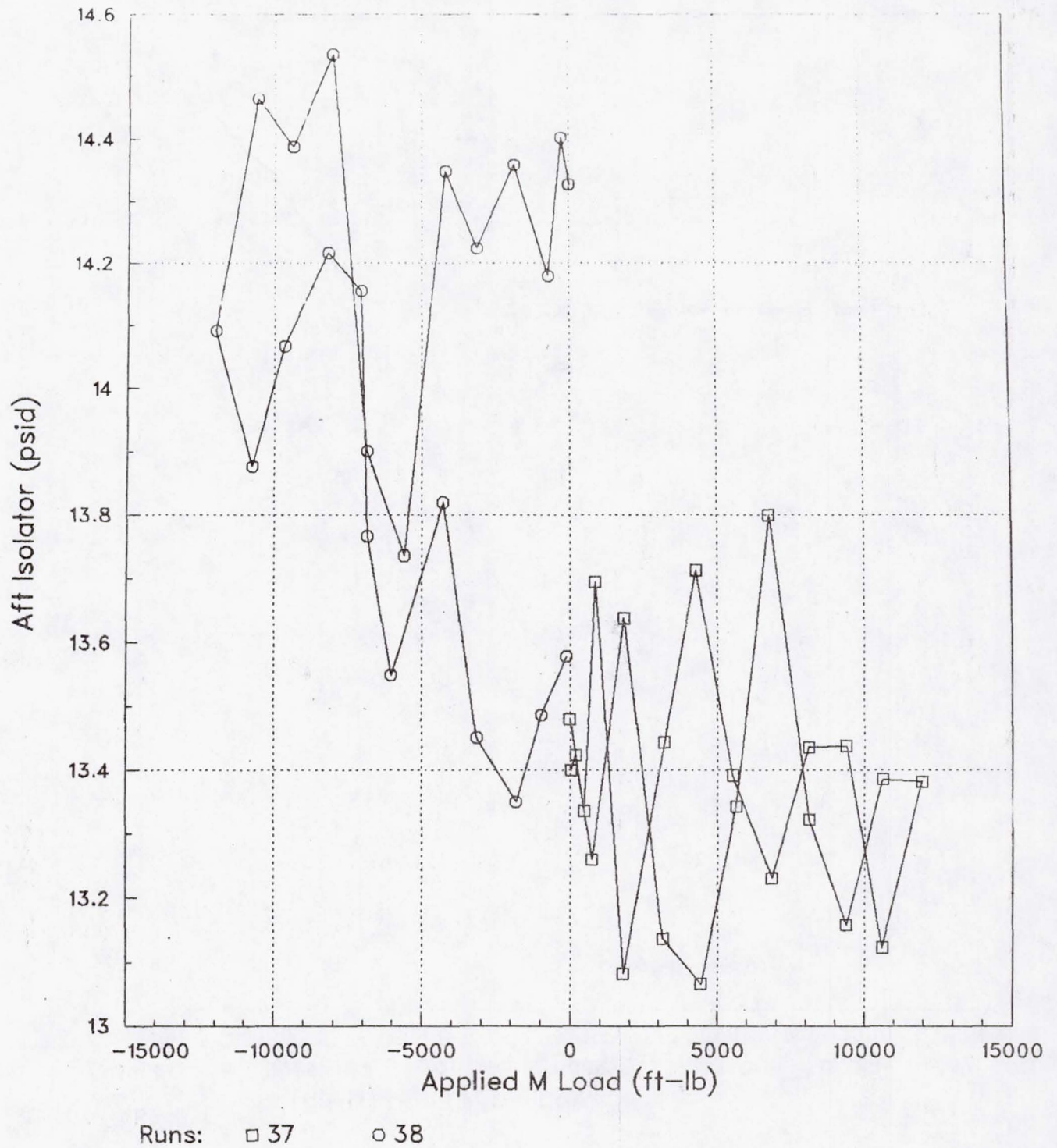


Runs: □ 37 ○ 38

RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

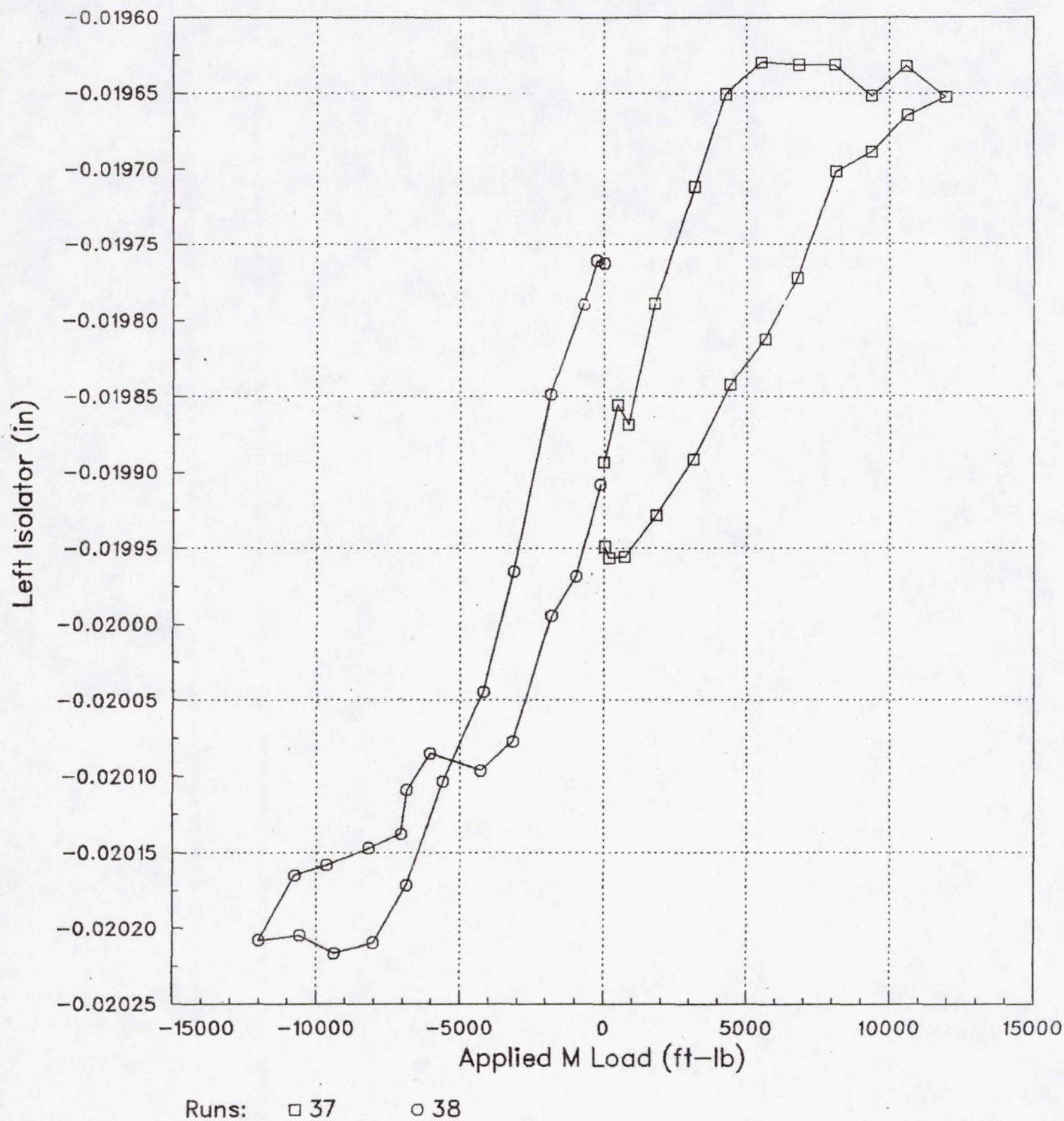
Constant Loads: 50% Z, 85% N



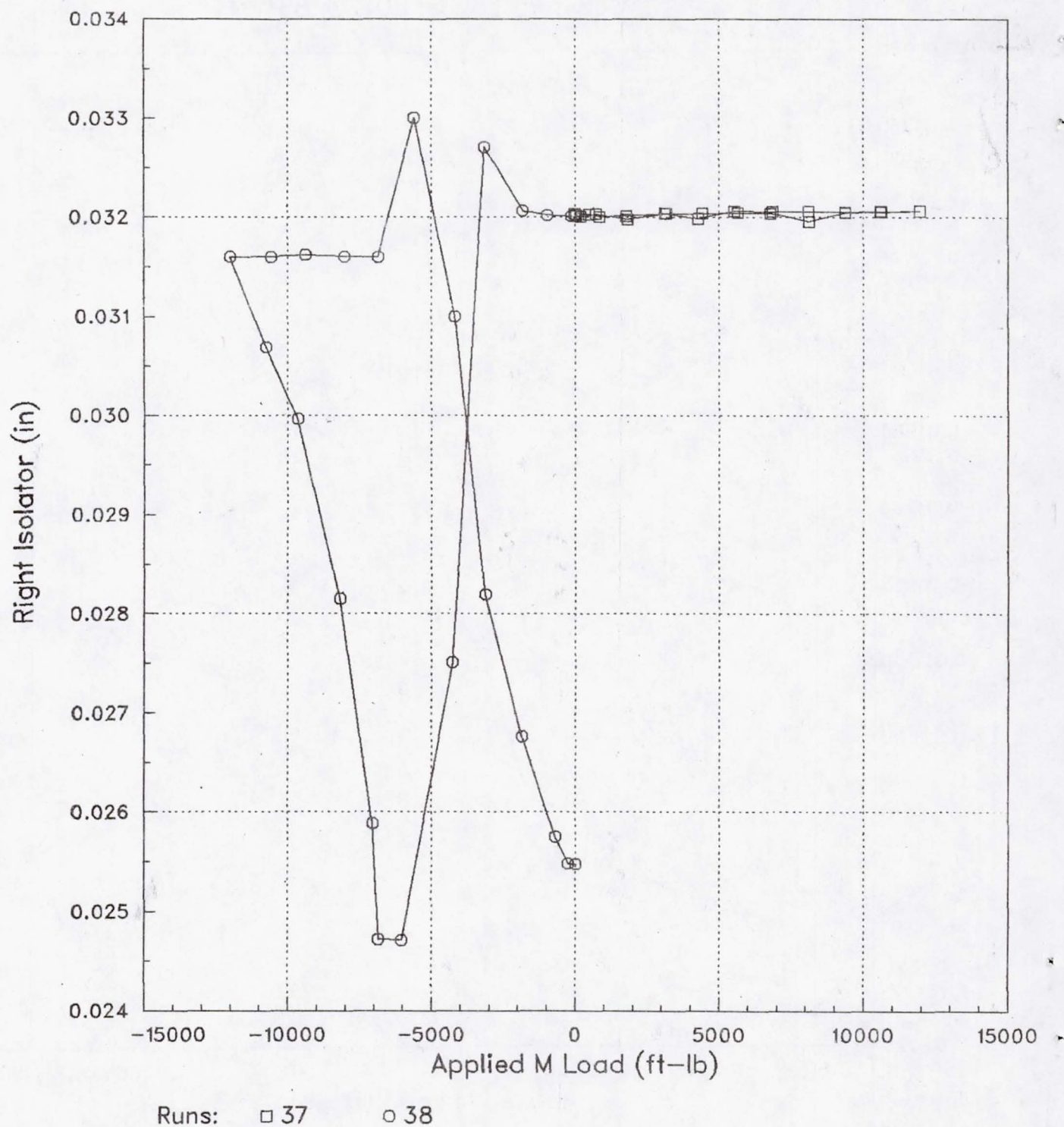
RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

Constant Loads: 50% Z, 85% N

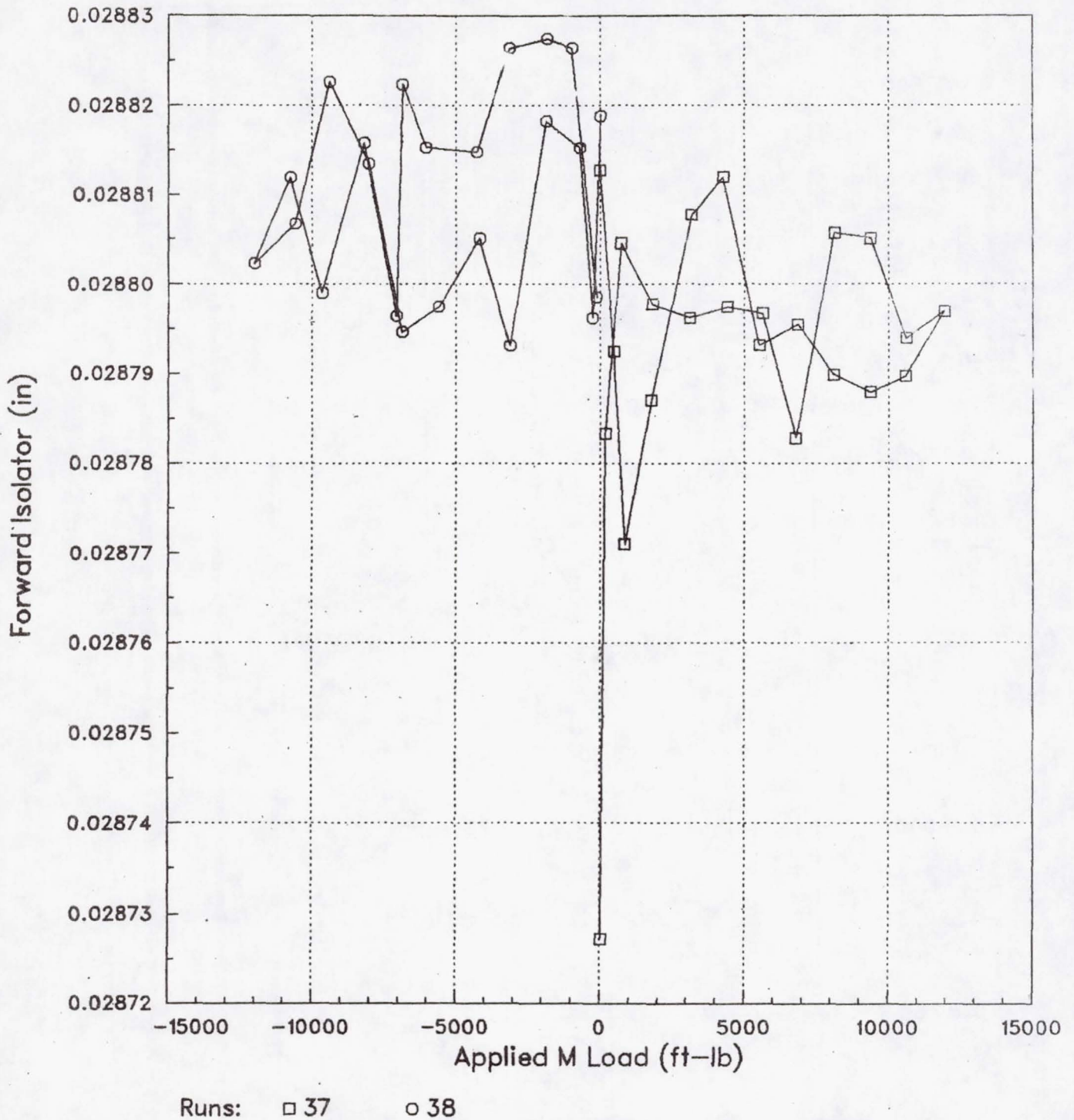


Applied M Load
Constant Loads: 50% Z, 85% N



RSRA 7-1 1983 ROTOR CALIBRATION

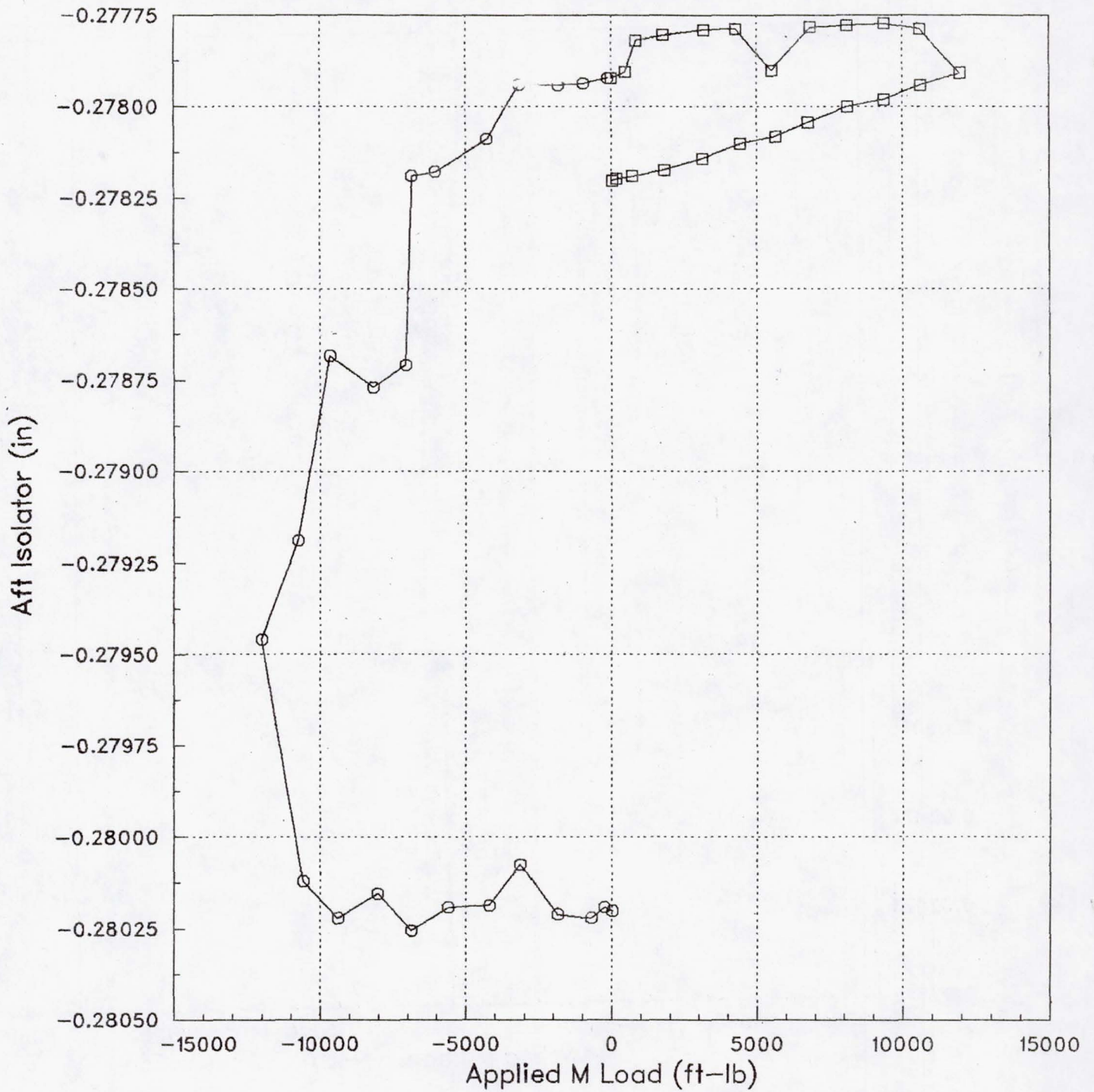
Applied M Load
Constant Loads: 50% Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

Constant Loads: 50% Z, 85% N

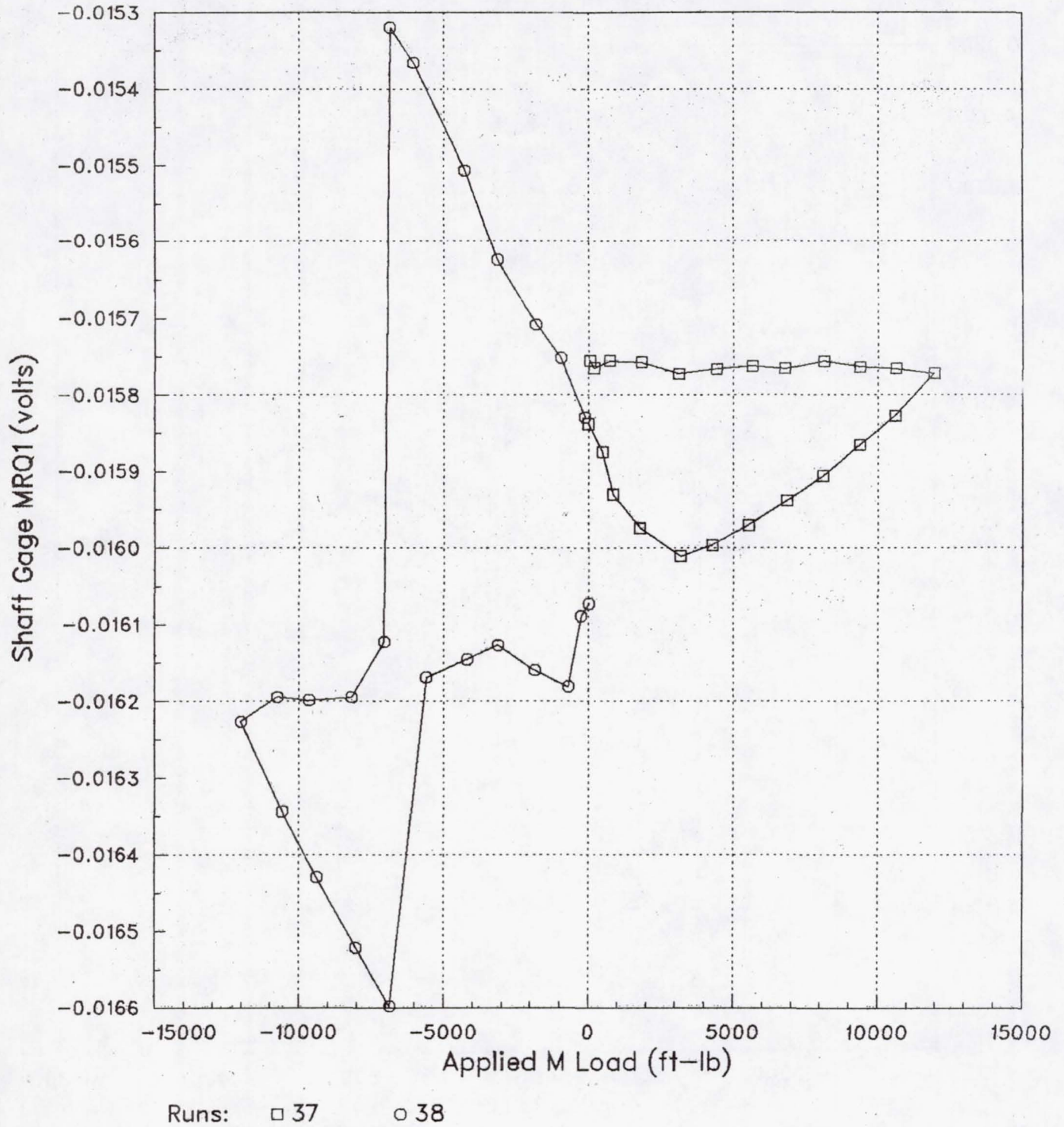


Runs: □ 37 ○ 38

RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

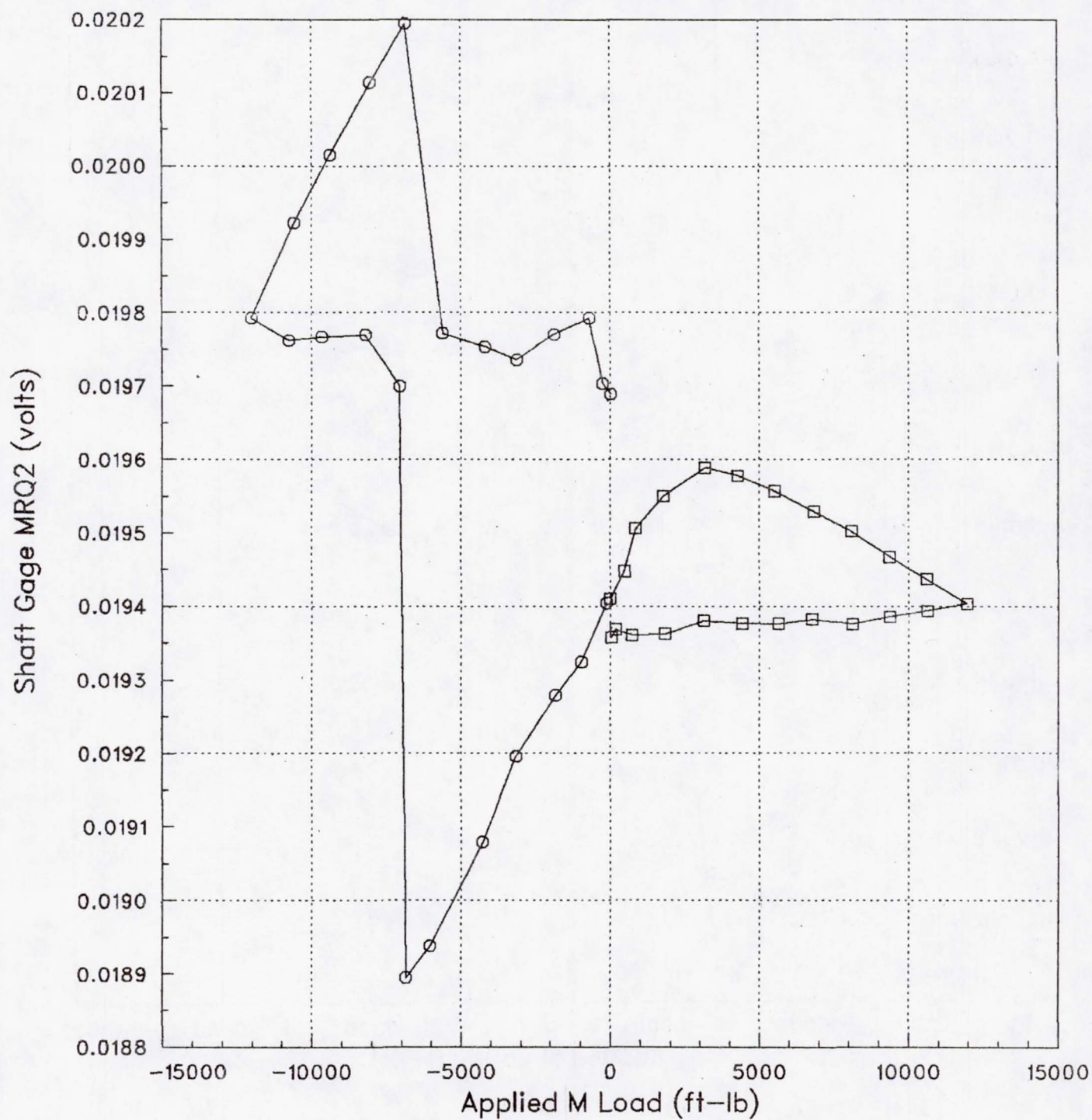
Constant Loads: 50% Z, 85% N



RSRA 741 1983 ROTOR CALIBRATION

Applied M Load

Constant Loads: 50% Z, 85% N

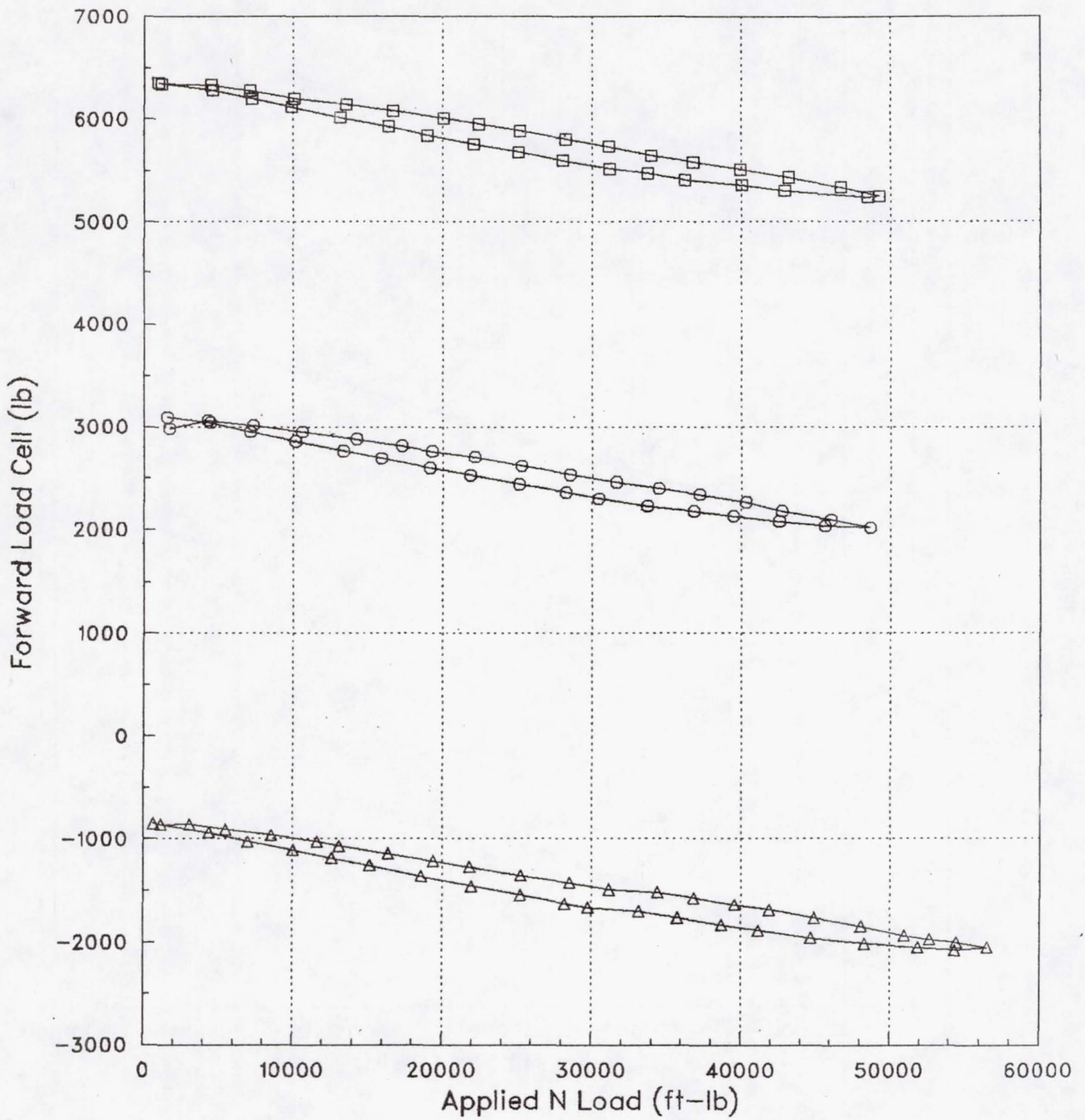


Runs: □ 37 ○ 38

RSRA 741 1983 ROTOR CALIBRATION

Applied N Load

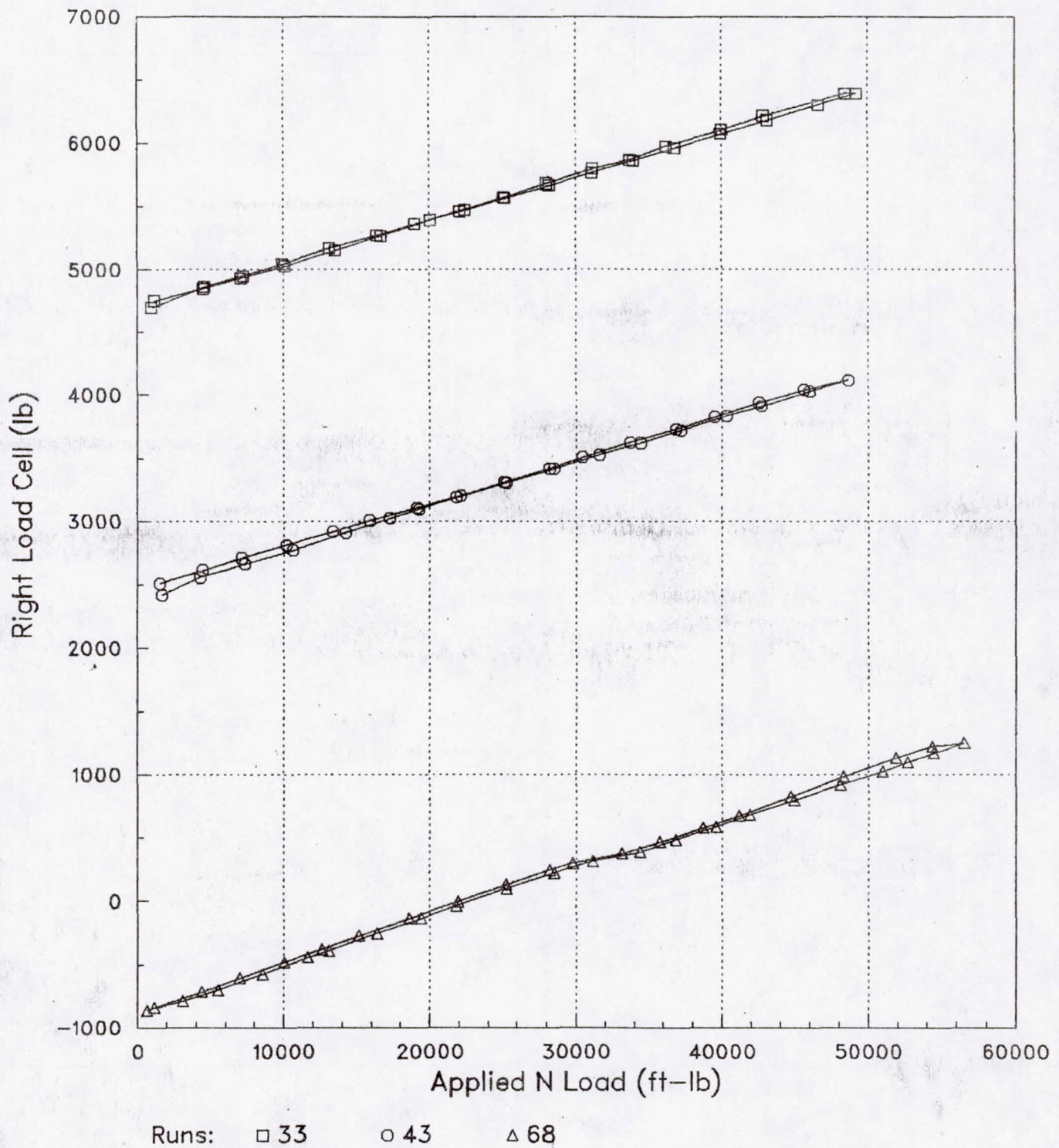
Constant Load: Z



Runs: □ 33 ○ 43 △ 68

RSRA - 41 1983 ROTOR CALIBRATION

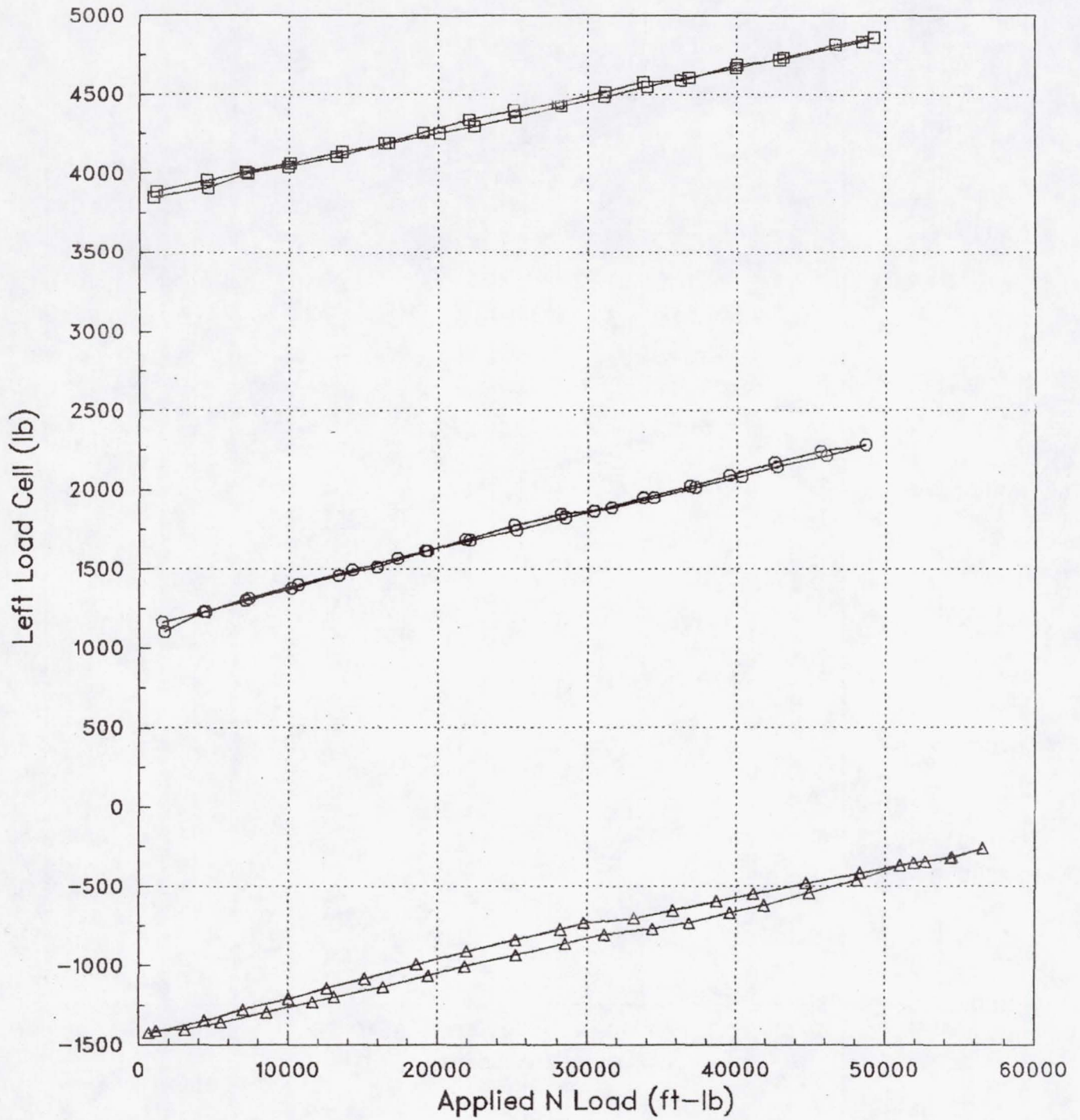
Applied N Load
Constant Load: Z



RSRA 741 1983 ROTOR CALIBRATION

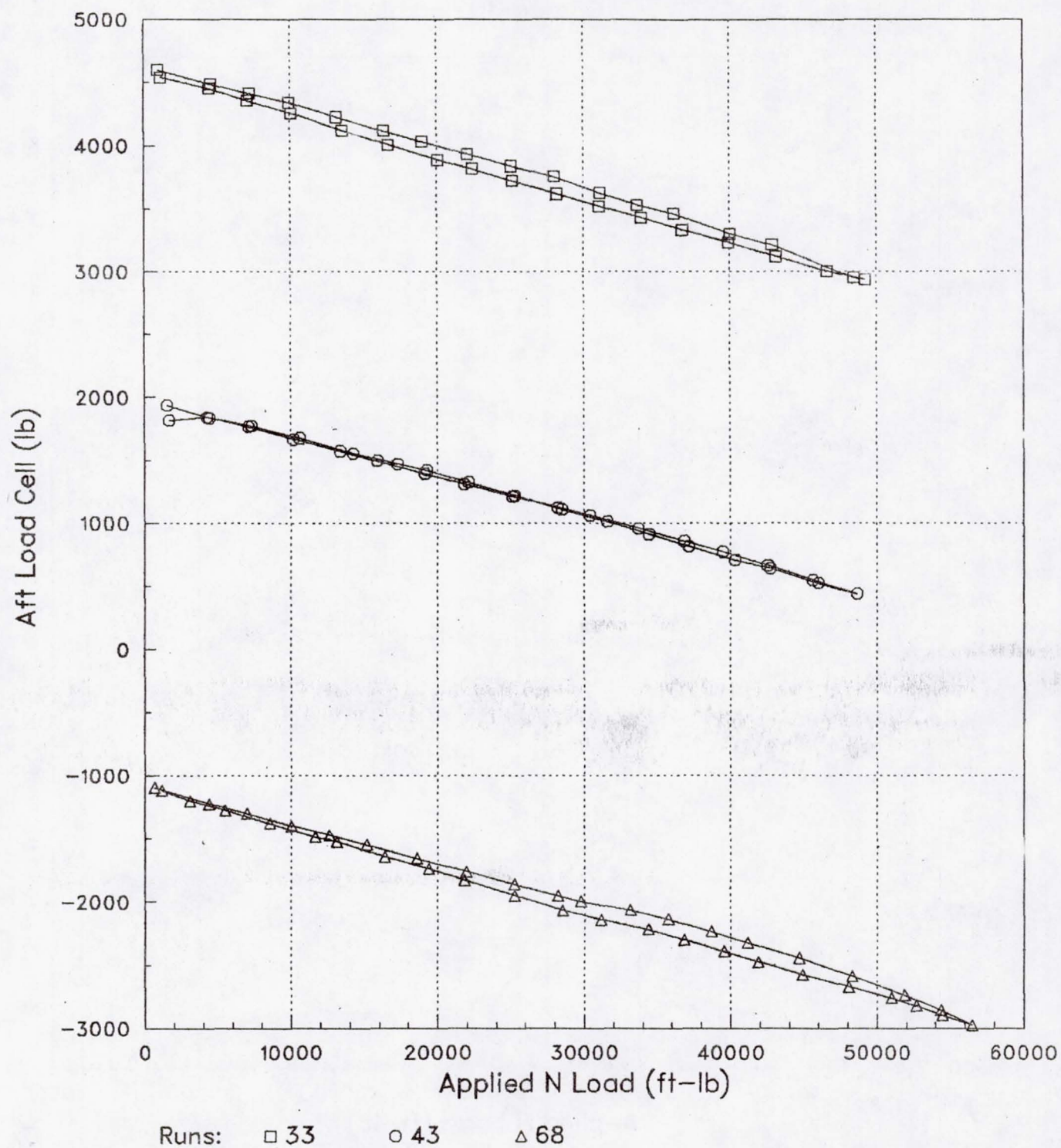
Applied N Load

Constant Load: Z



Runs: □ 33 ○ 43 △ 68

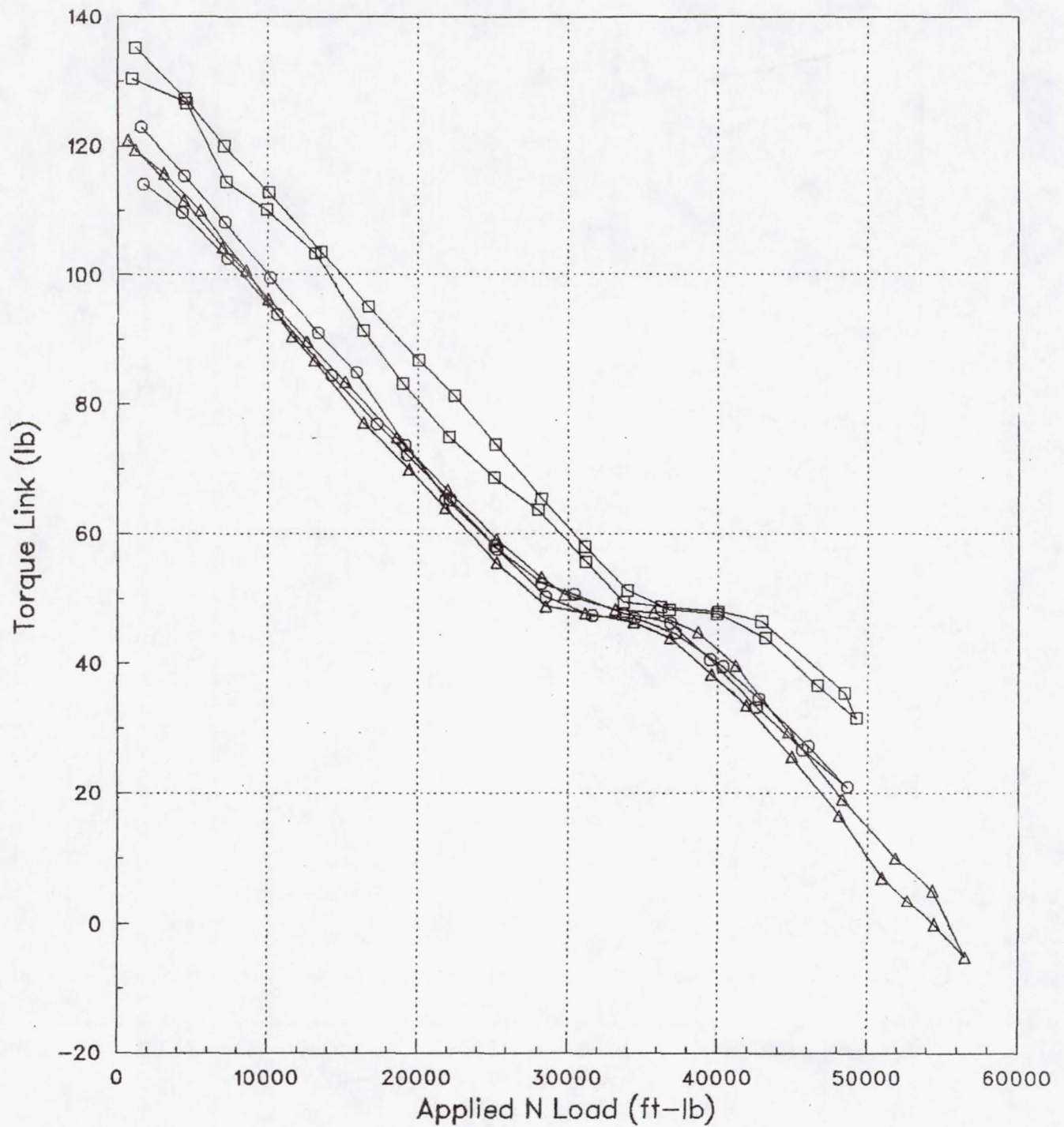
Applied N Load
Constant Load: Z



RSRA 741 1983 ROTOR CALIBRATION

Applied N Load

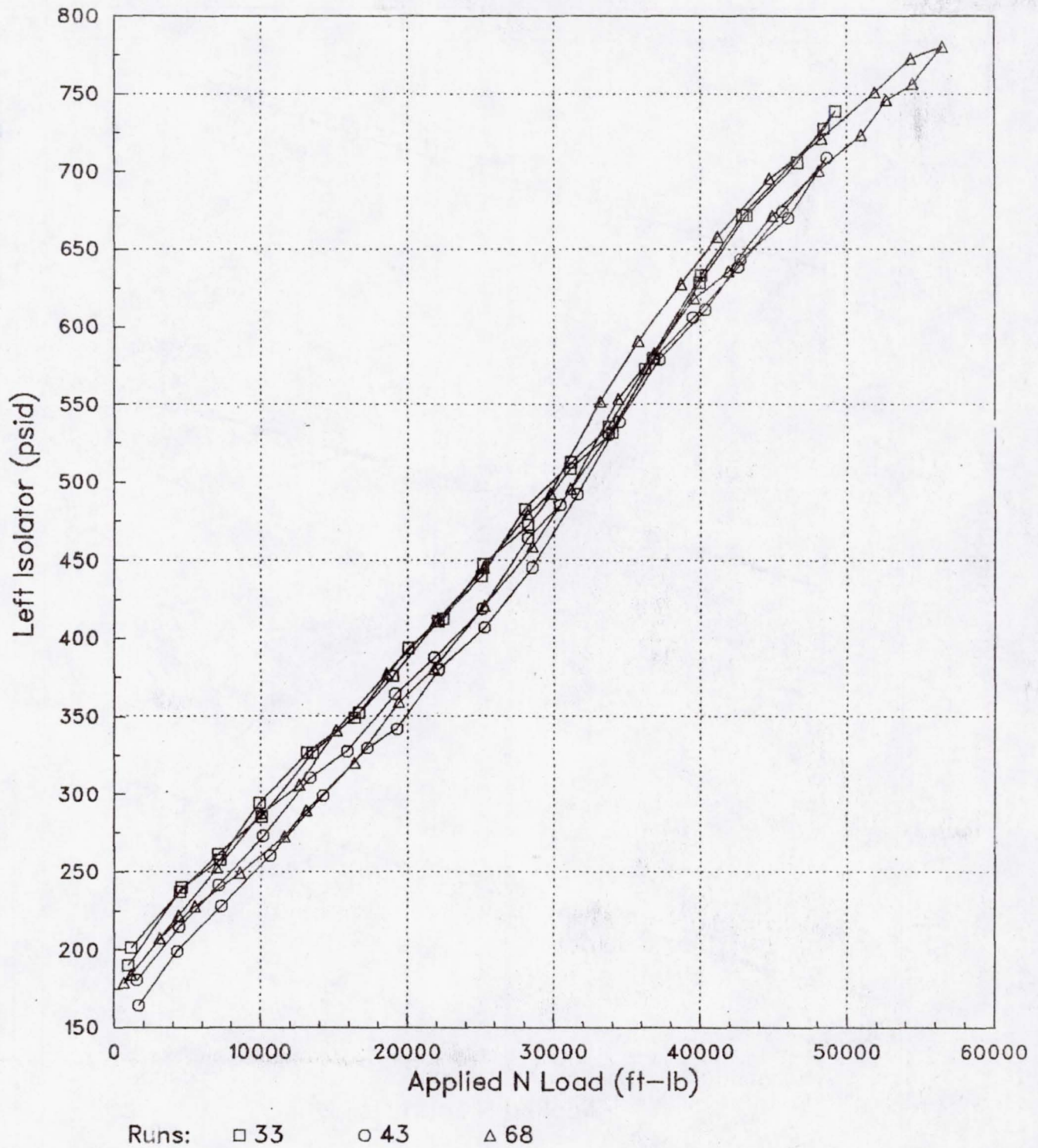
Constant Load: Z



Runs: □ 33 ○ 43 △ 68

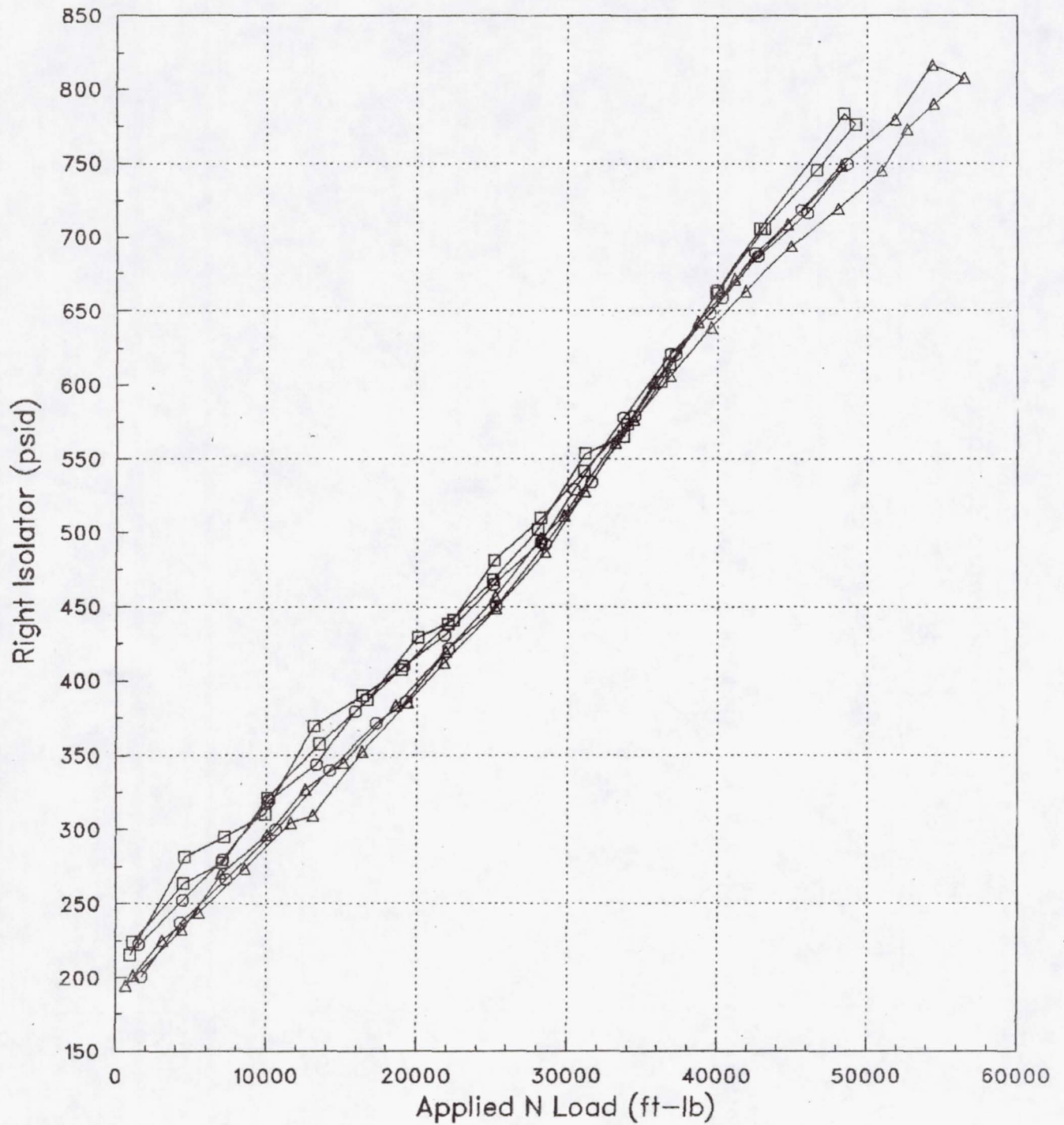
RSFA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Load: Z



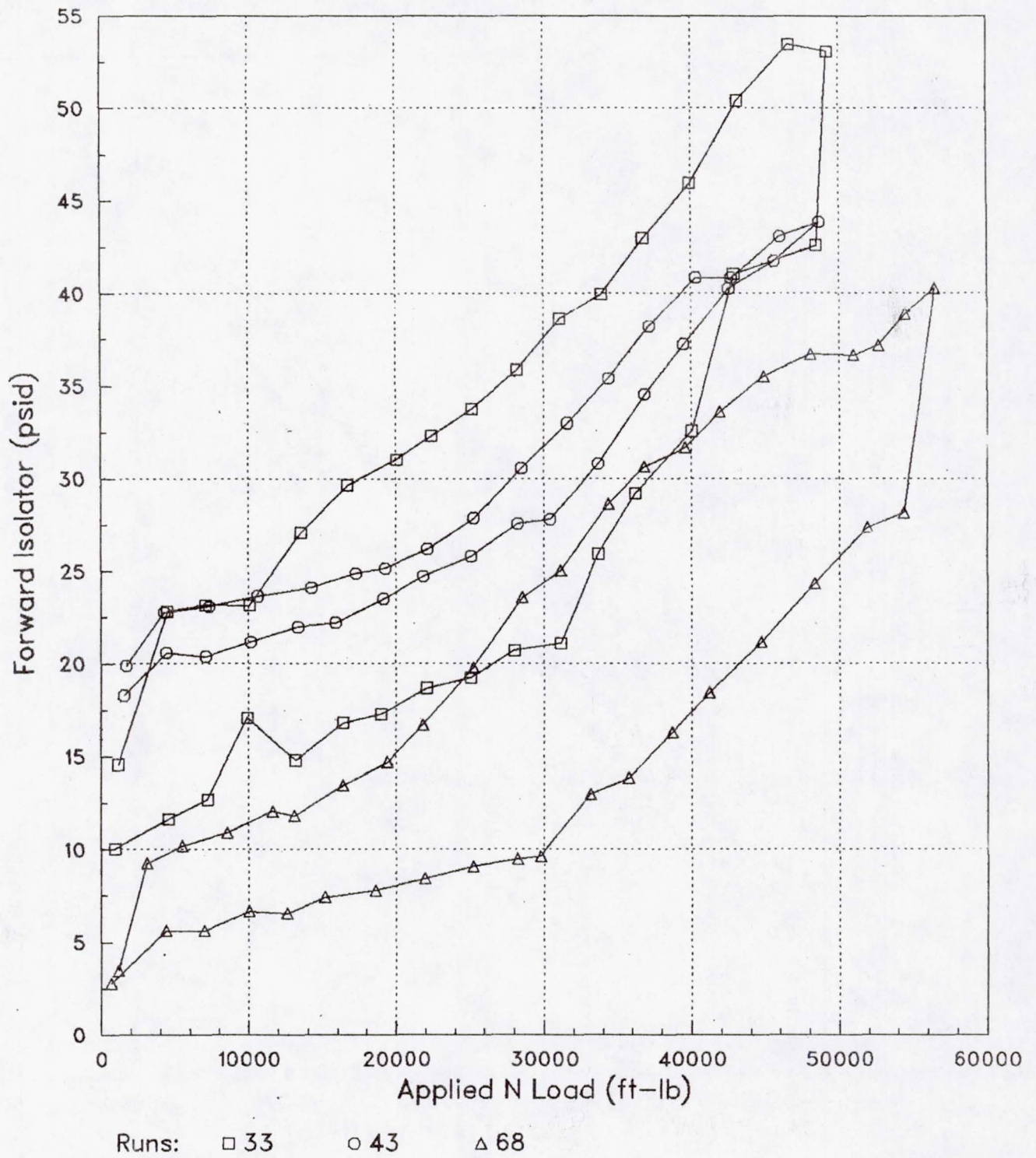
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Load: Z



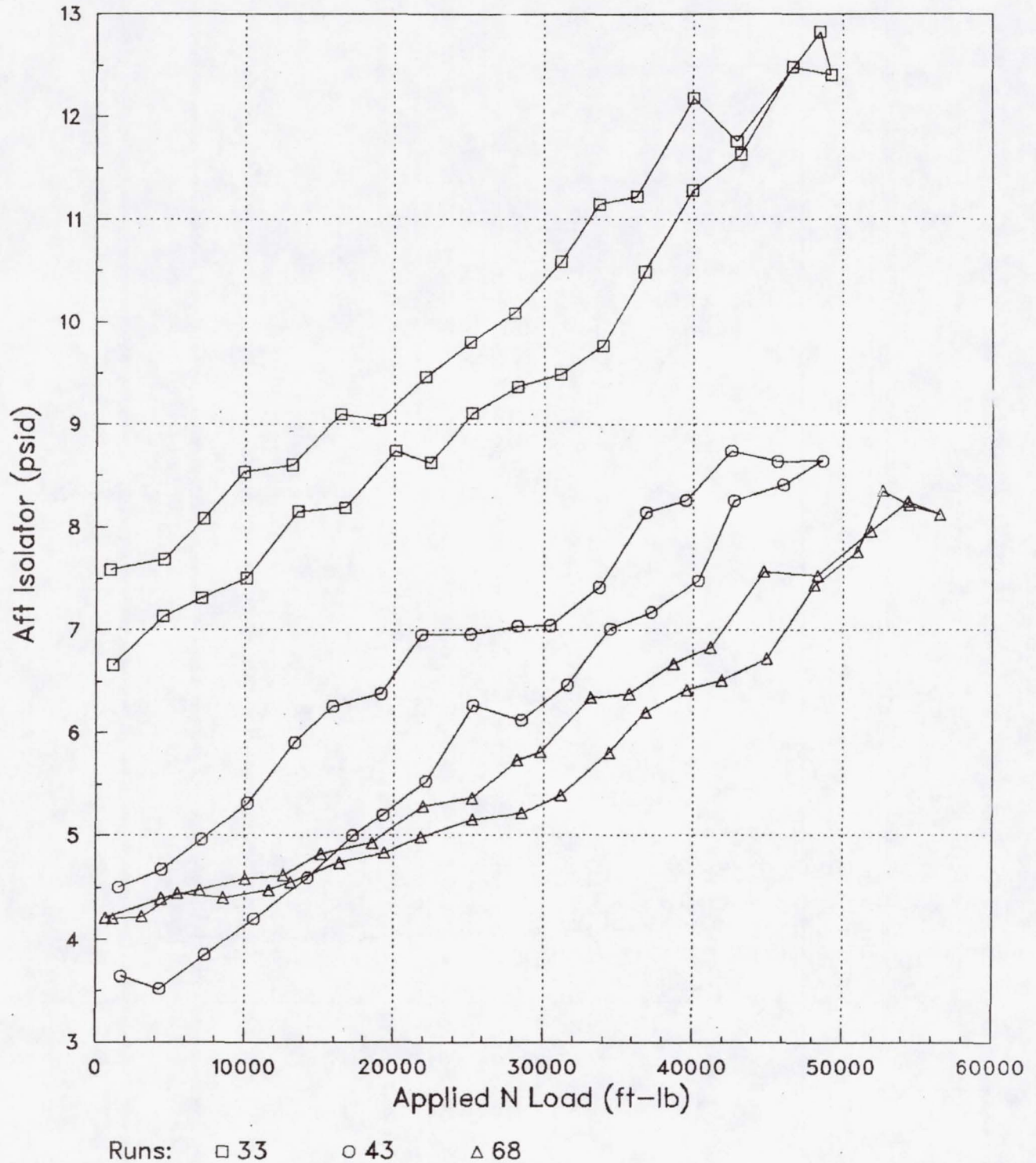
Runs: □ 33 ○ 43 △ 68

Applied N Load
Constant Load: Z



RSRA 741 1983 ROTOR CALIBRATION

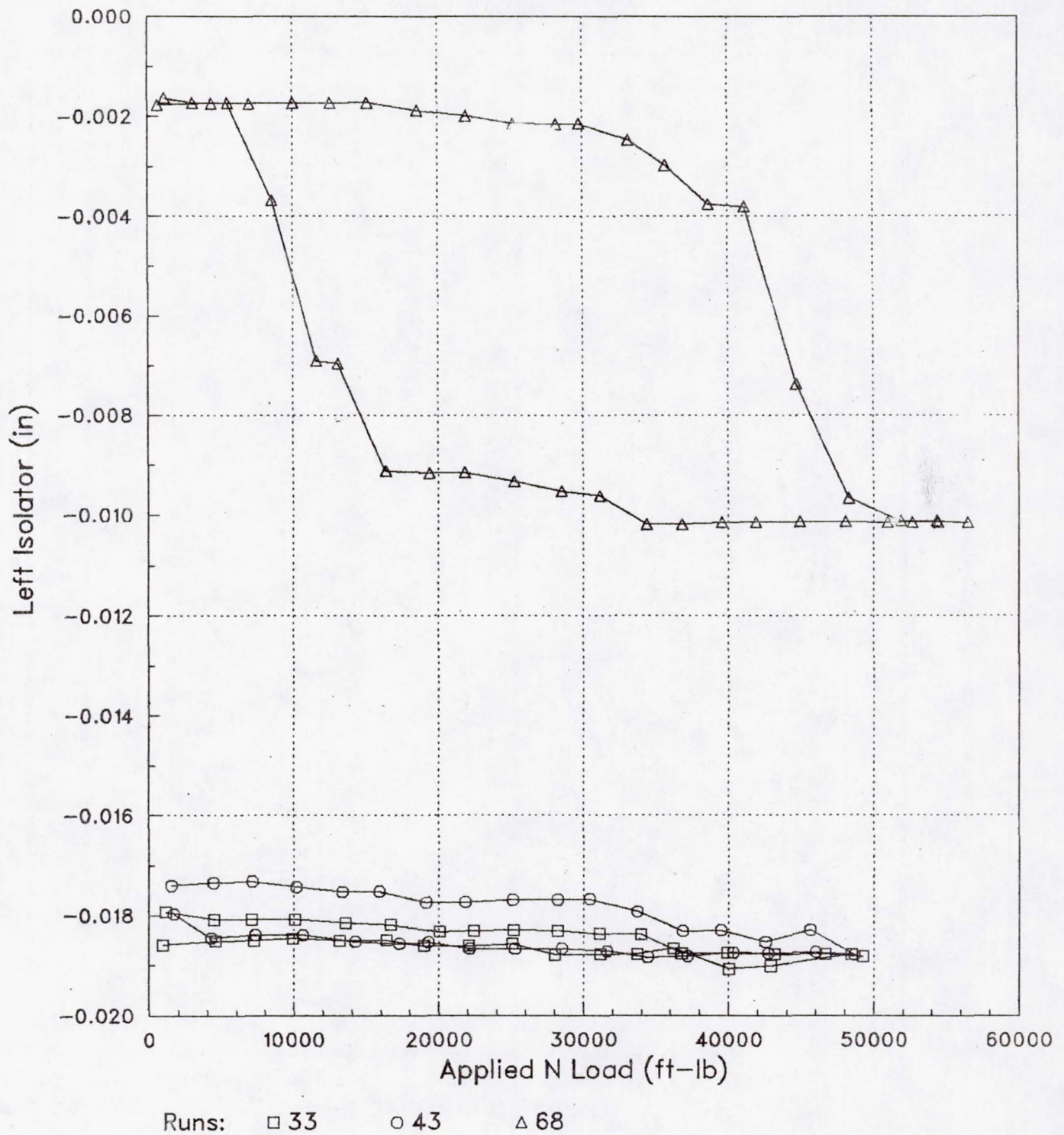
Applied N Load
Constant Load: Z



RSRA 741 1983 ROTOR CALIBRATION

Applied N Load

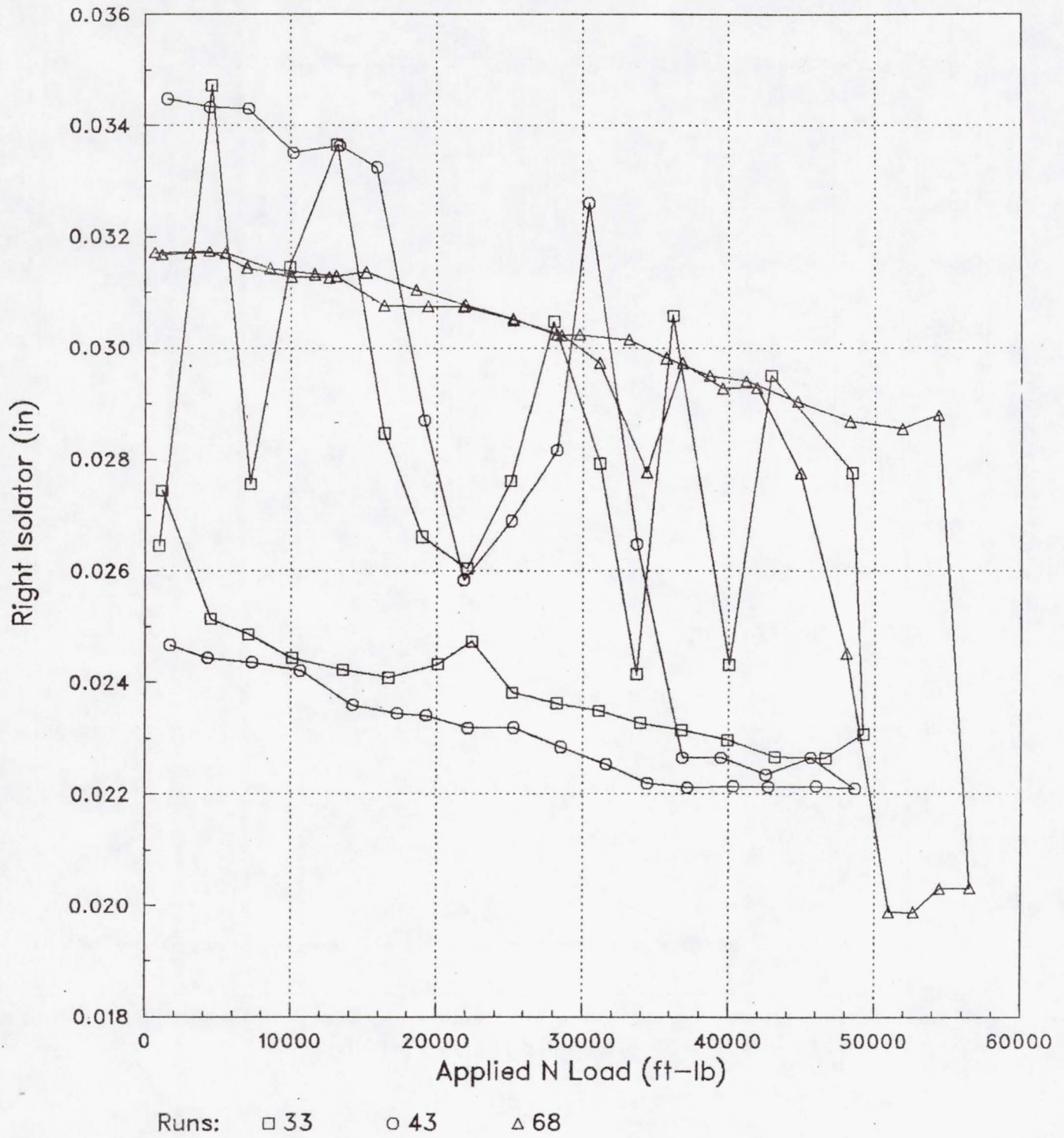
Constant Load: Z



RSRA 741 1983 ROTOR CALIBRATION

Applied N Load

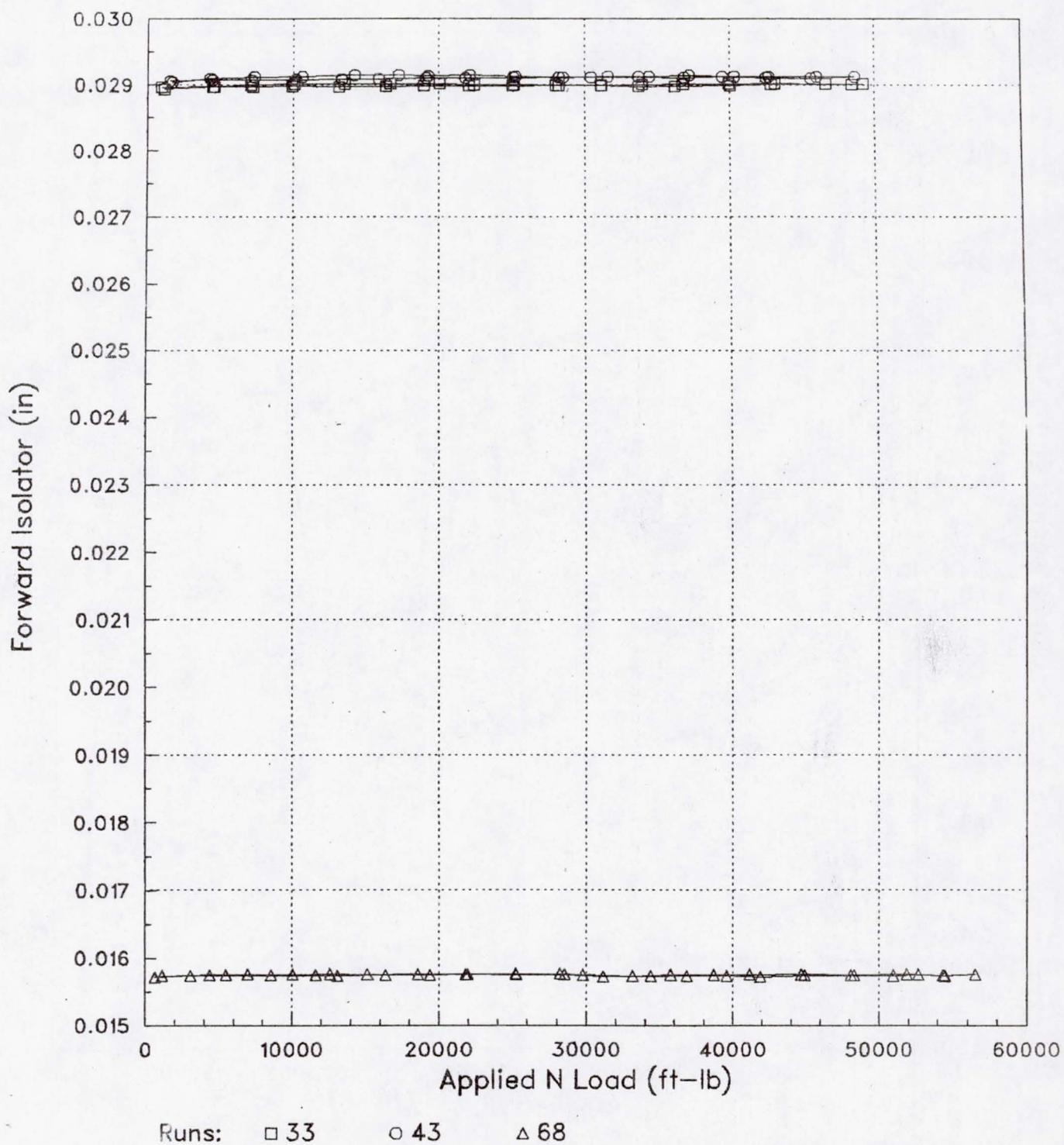
Constant Load: Z



RSRA 741 1983 ROTOR CALIBRATION

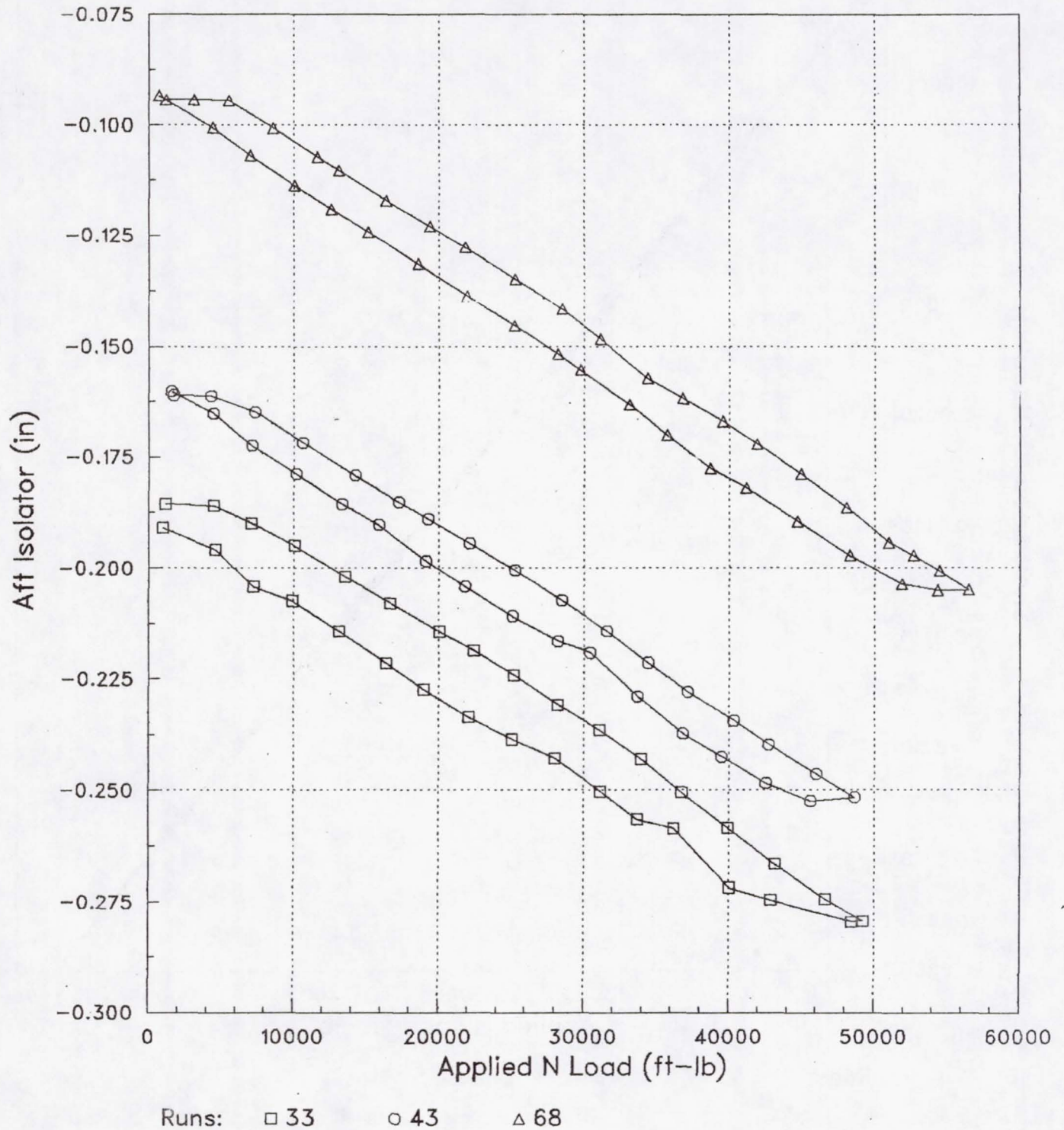
Applied N Load

Constant Load: Z



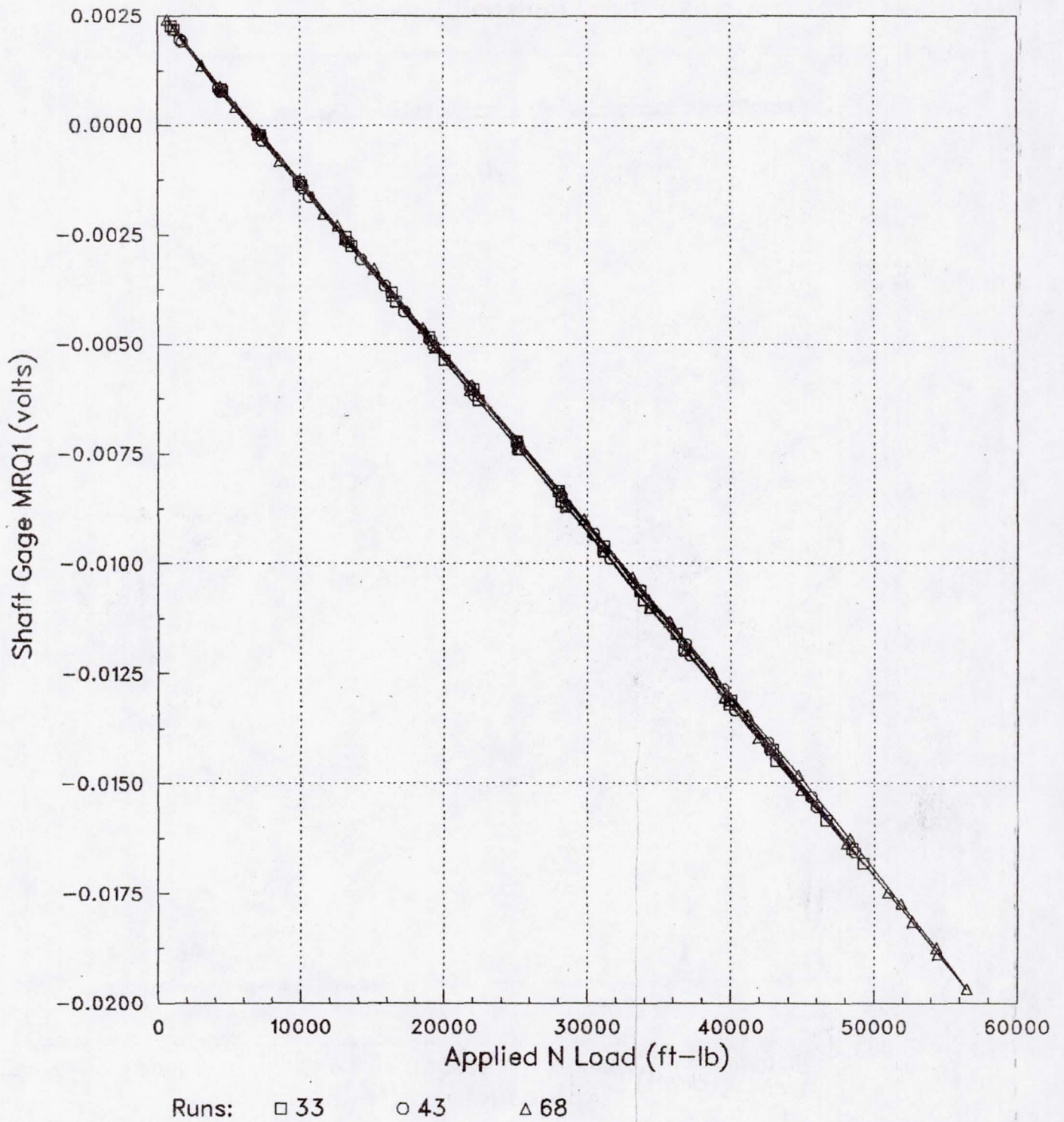
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Load: Z



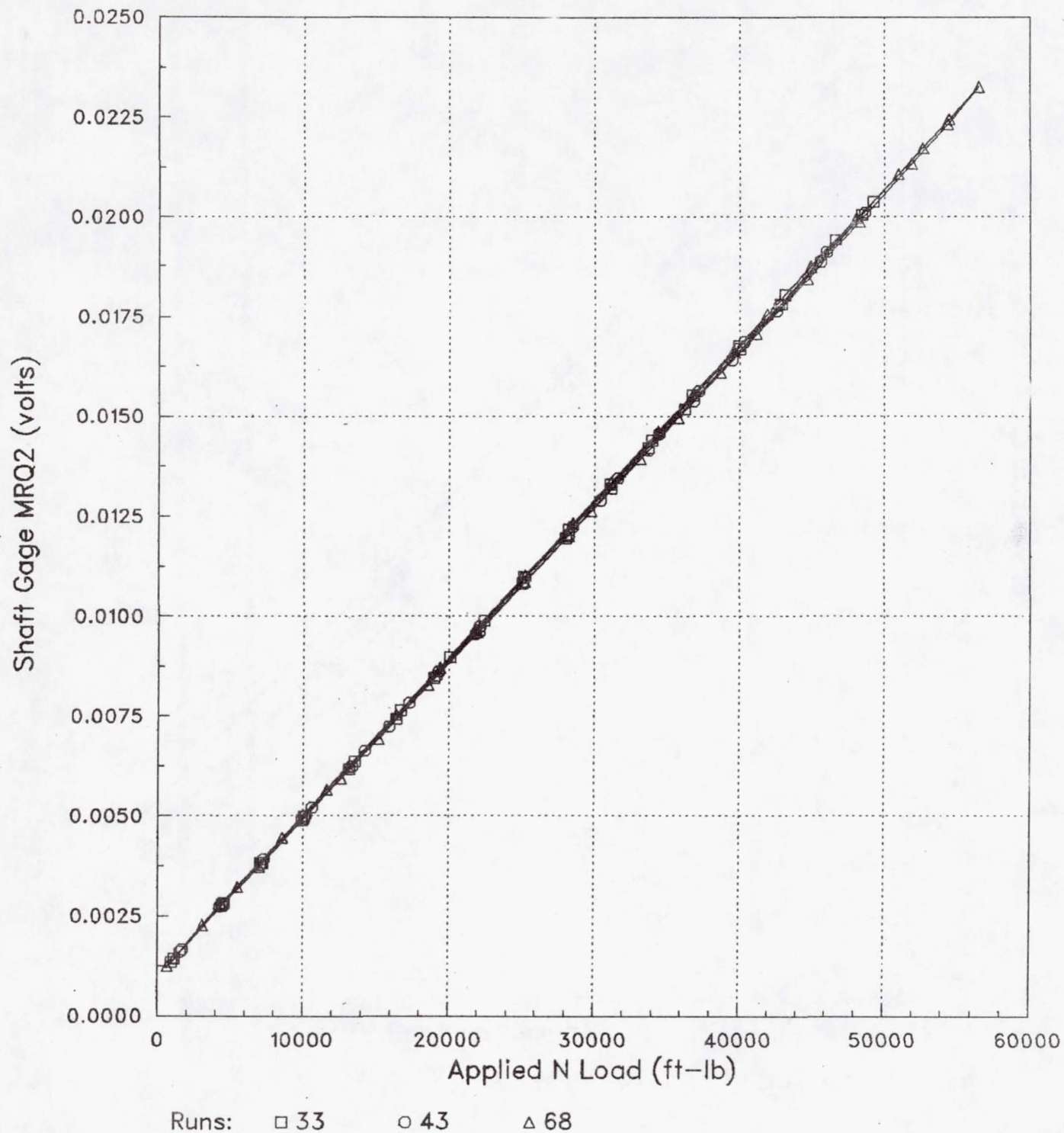
RSRA 741 1983 ROTOR CALIBRATION

Applied N Load
Constant Load: Z



RSRA 741 1983 ROTOR CALIBRATION

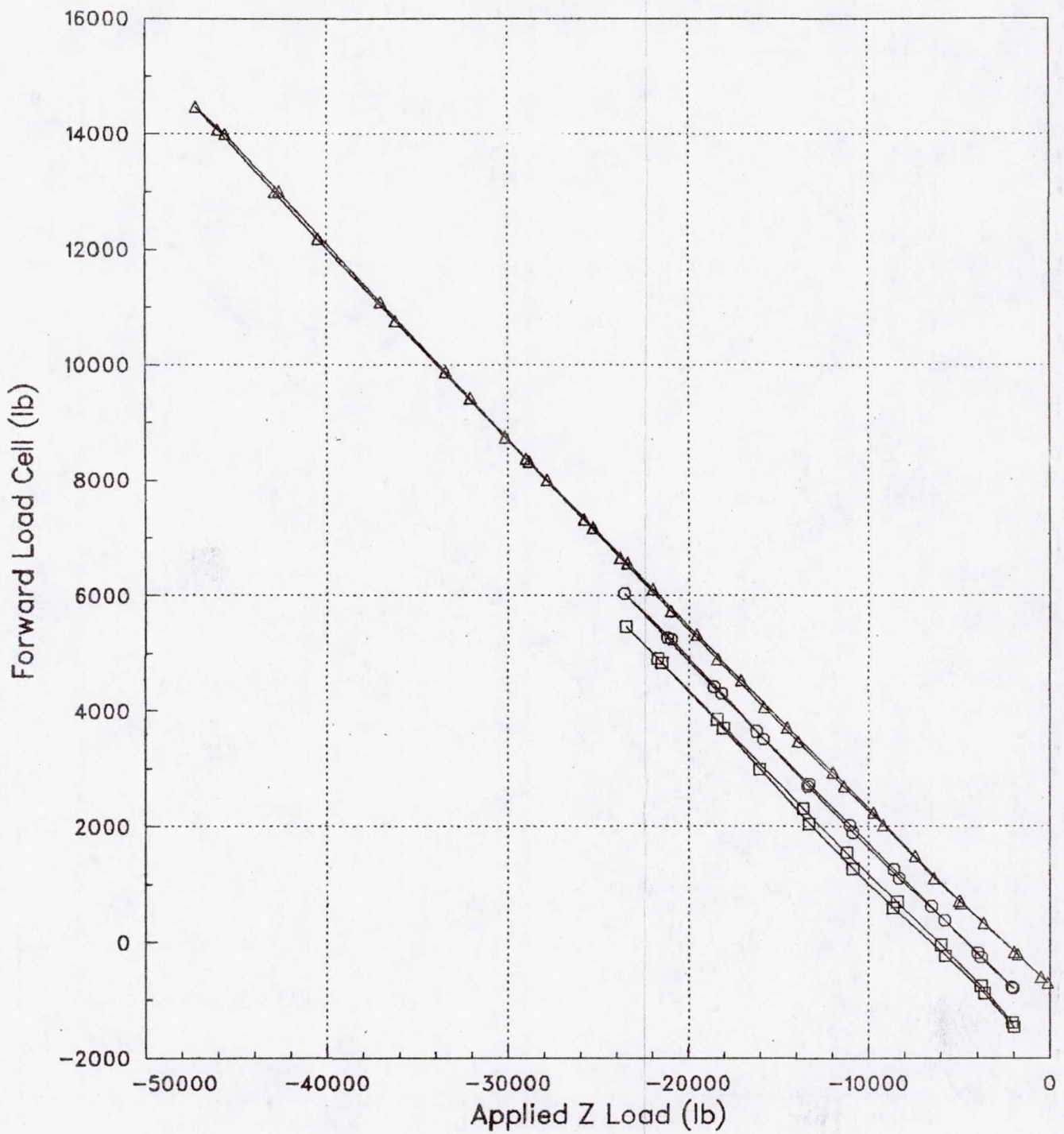
Applied N Load
Constant Load: Z



RSNA 741 1983 ROTOR CALIBRATION

Applied Z Load

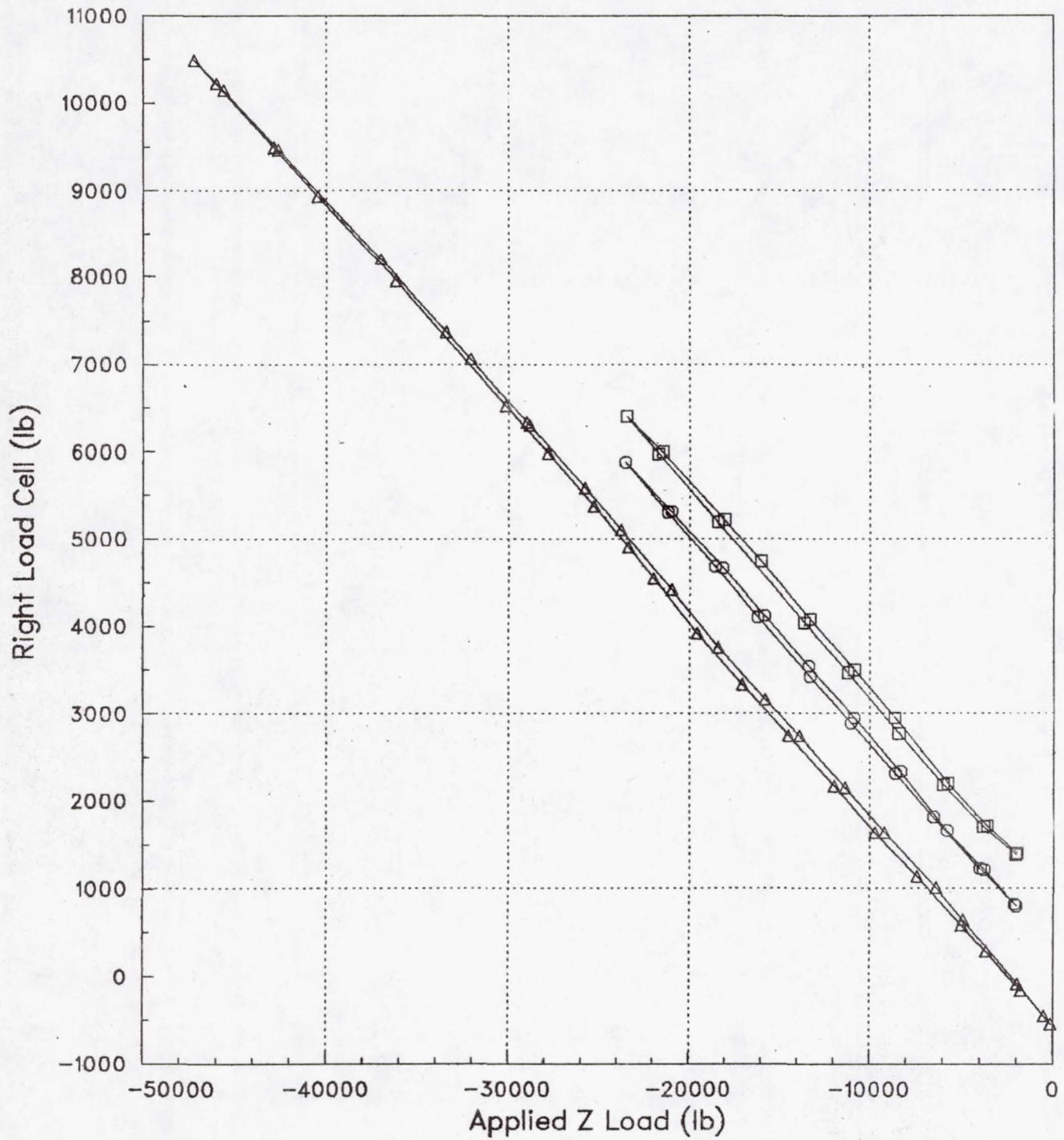
Constant Load: N



RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load

Constant Load: N

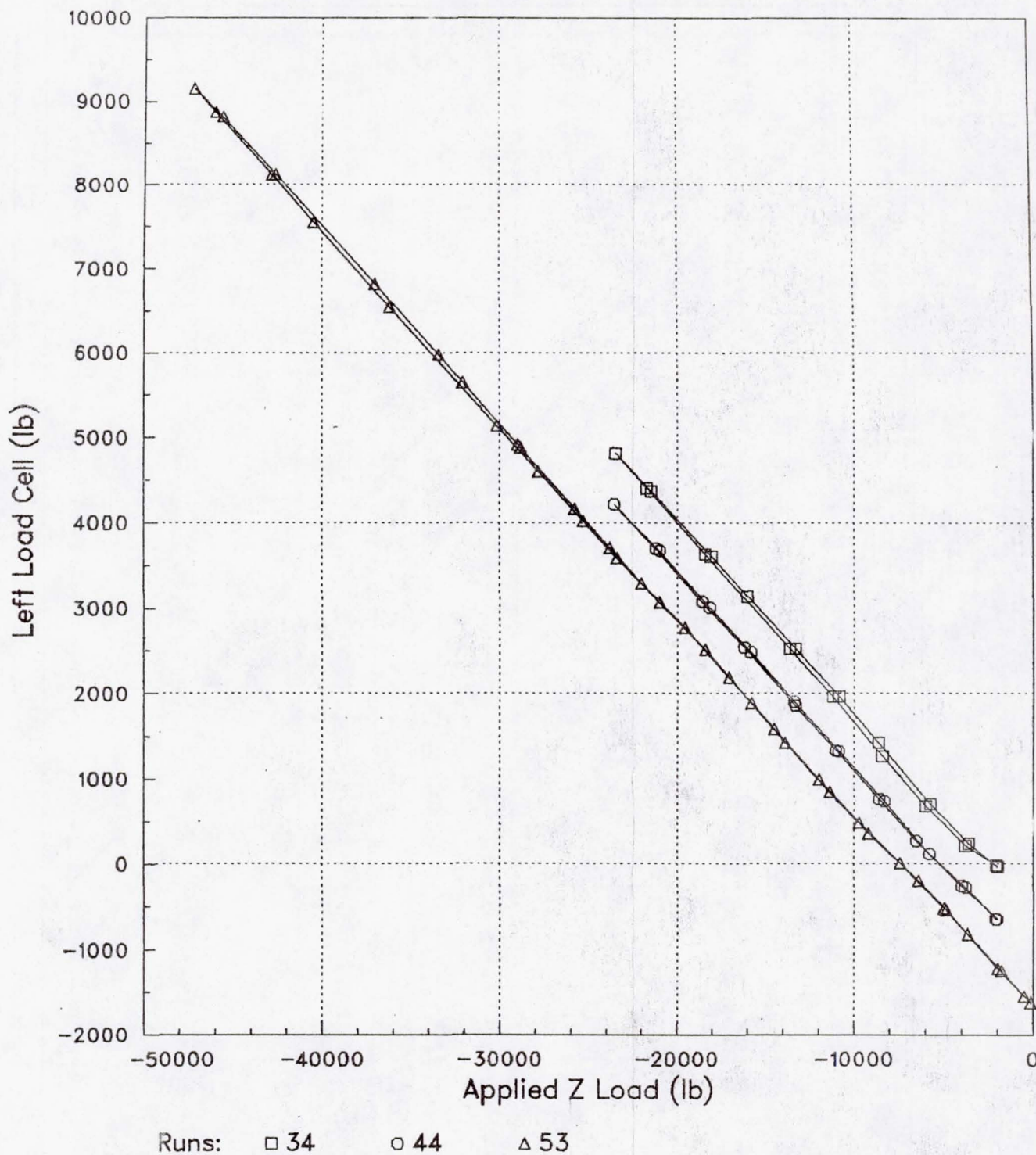


Runs: □ 34 ○ 44 △ 53

RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load

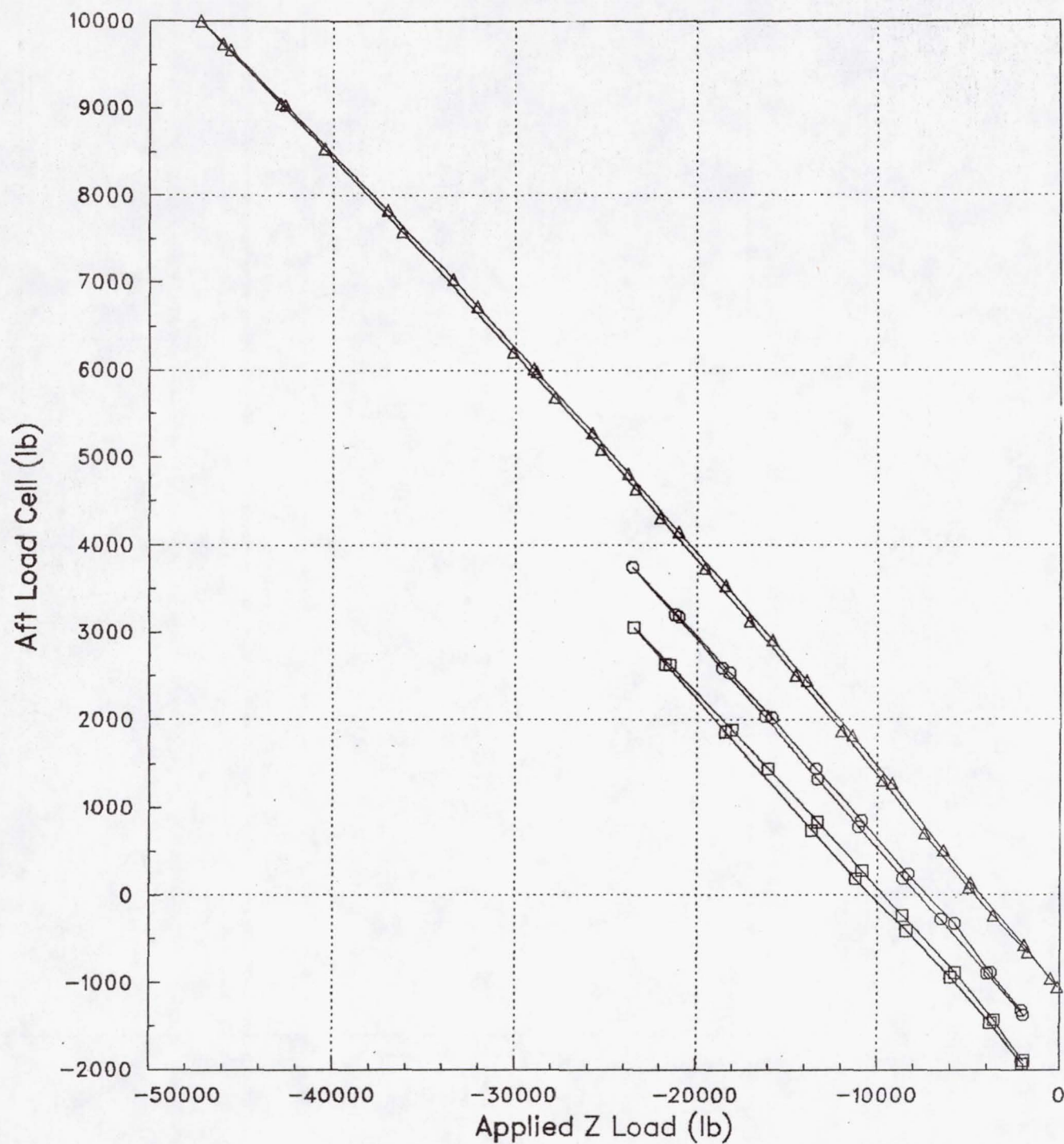
Constant Load: N



RSRA 741 1983 ROTOR CALIBRATION

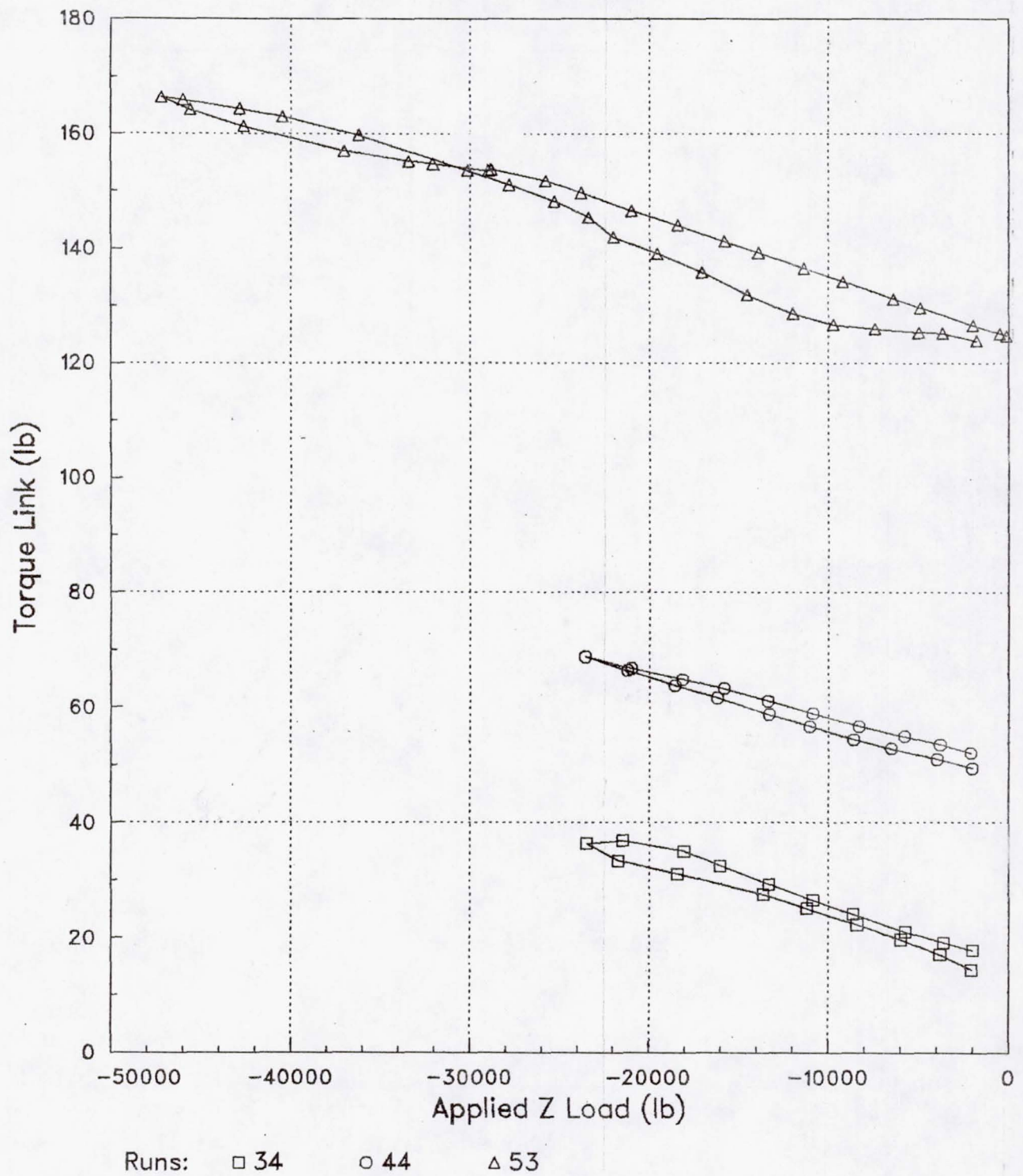
Applied Z Load

Constant Load: N



PSRA 741 1983 ROTOR CALIBRATION

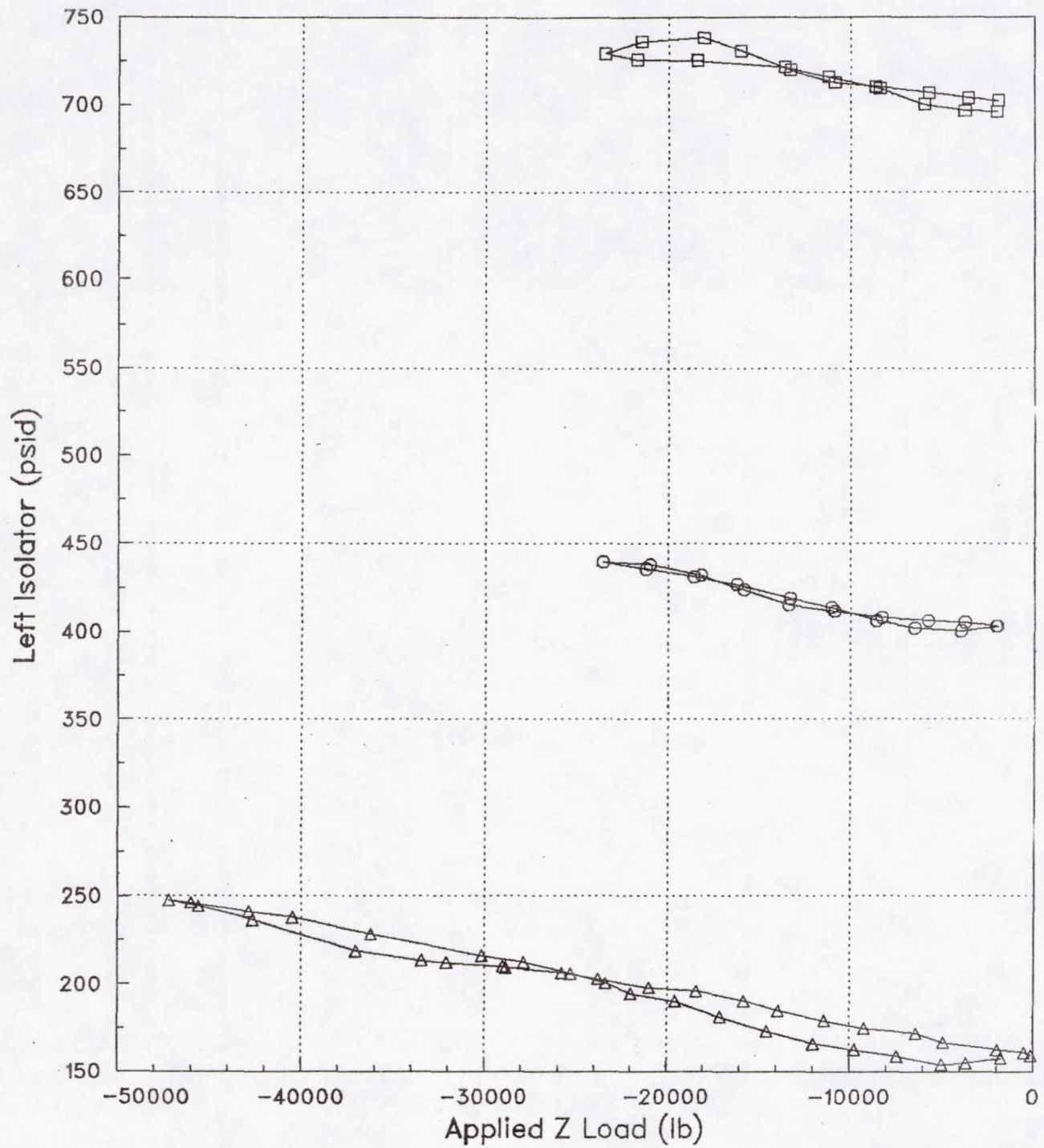
Applied Z Load
Constant Load: N



RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load

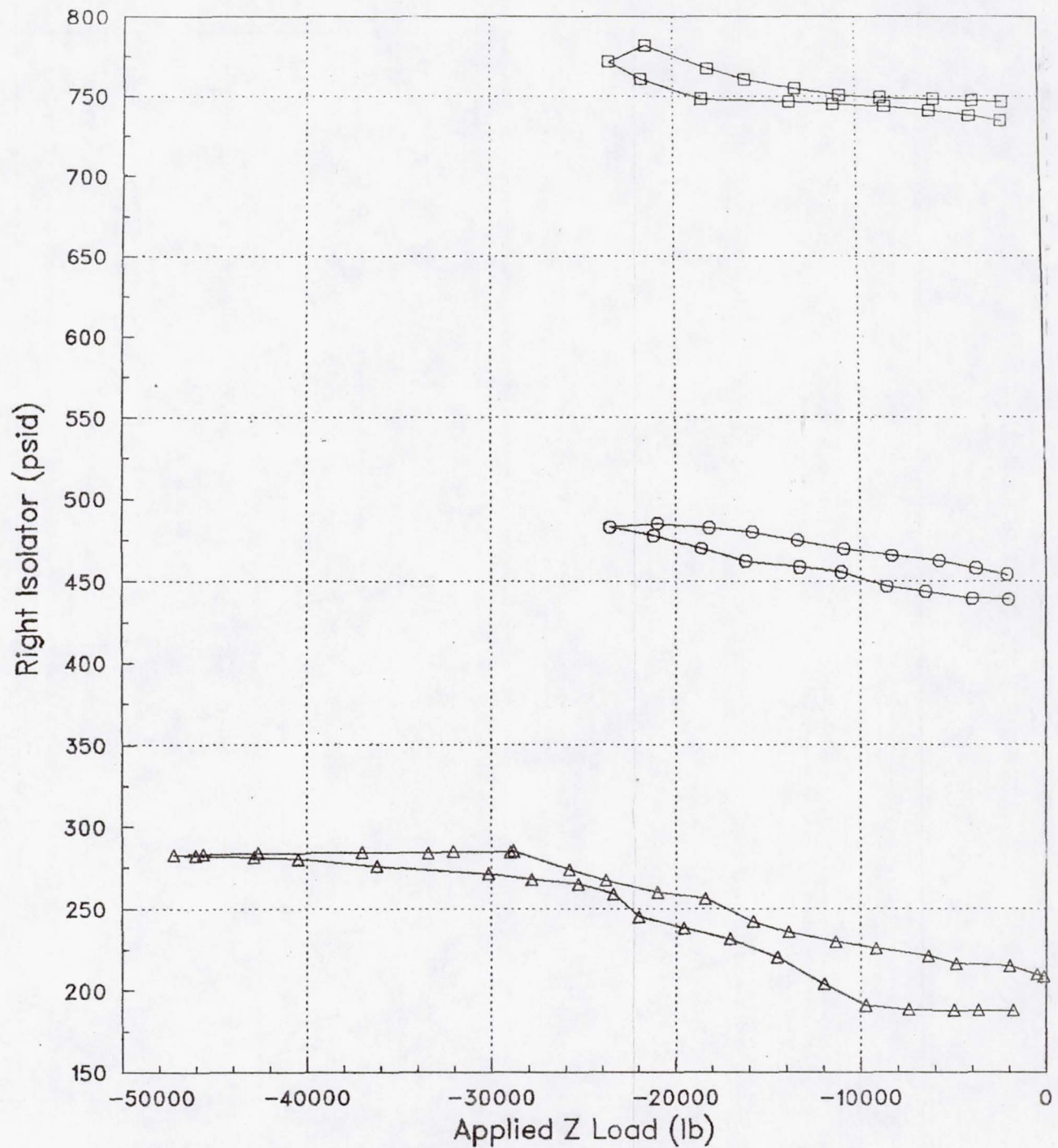
Constant Load: N



Runs: □ 34 ○ 44 △ 53

Applied Z Load

Constant Load: N

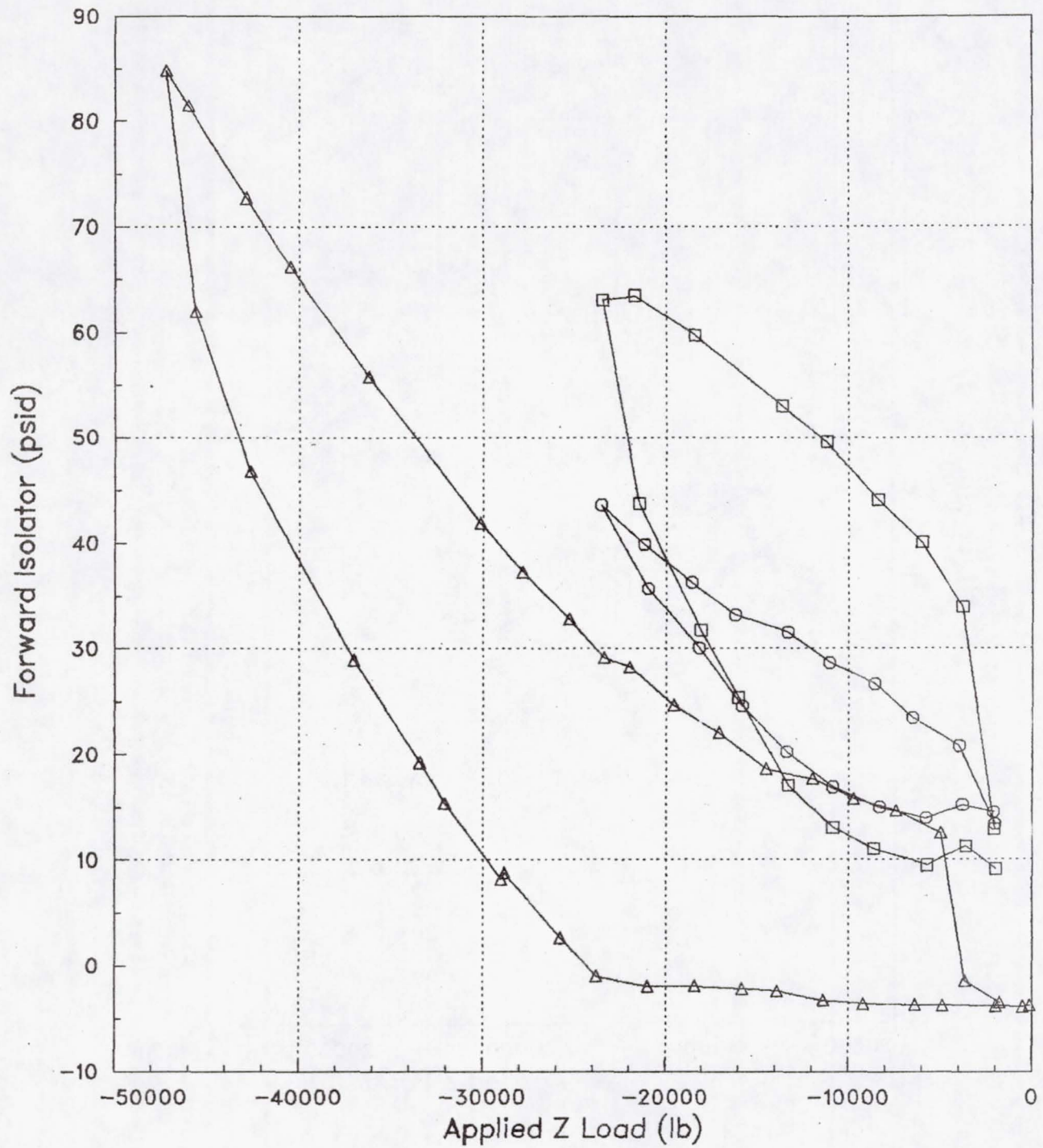


Runs: □ 34 ○ 44 △ 53

RSRA 741 1983 ROTOR CALIBRATION

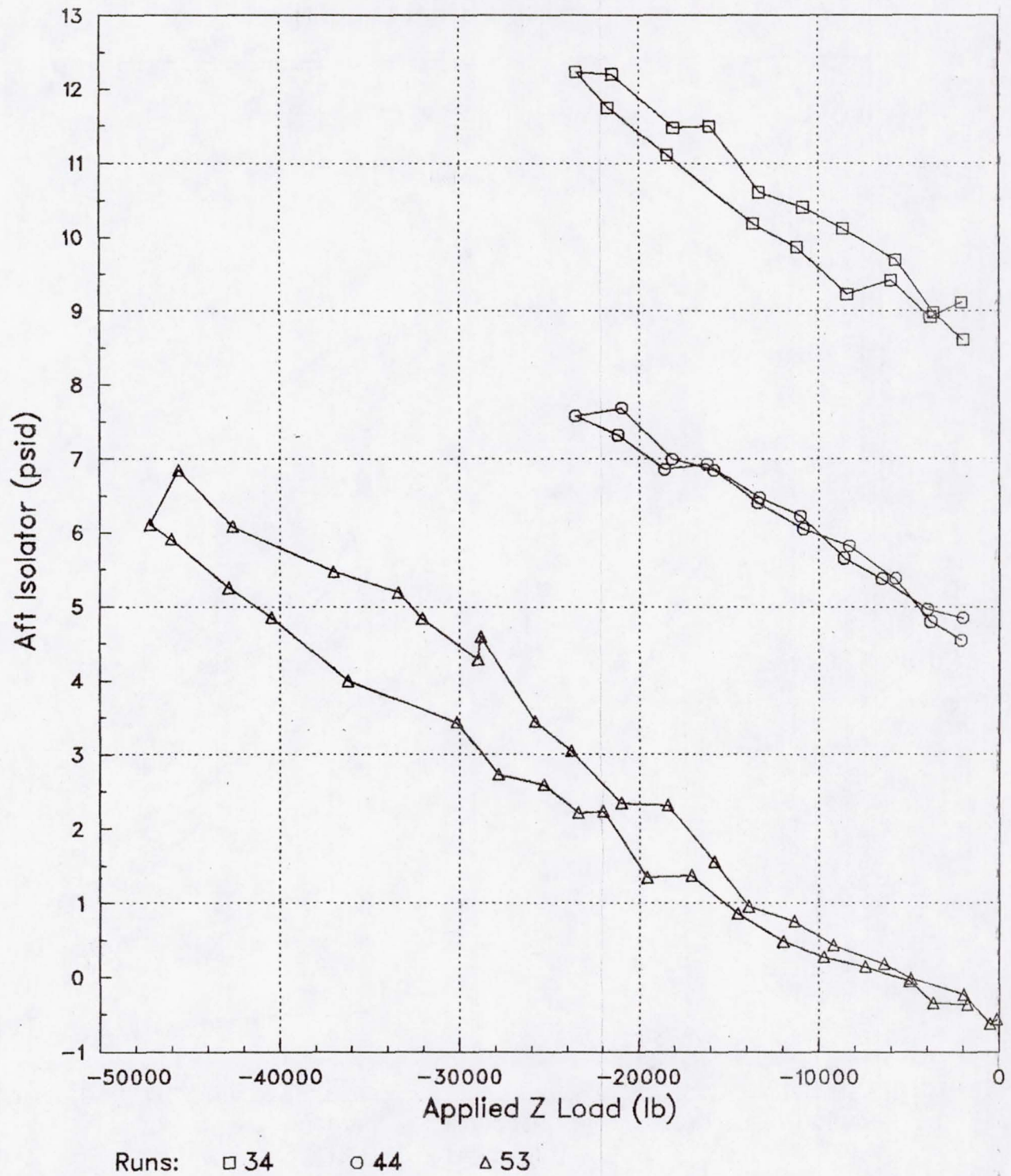
Applied Z Load

Constant Load: N



Runs: □ 34 ○ 44 △ 53

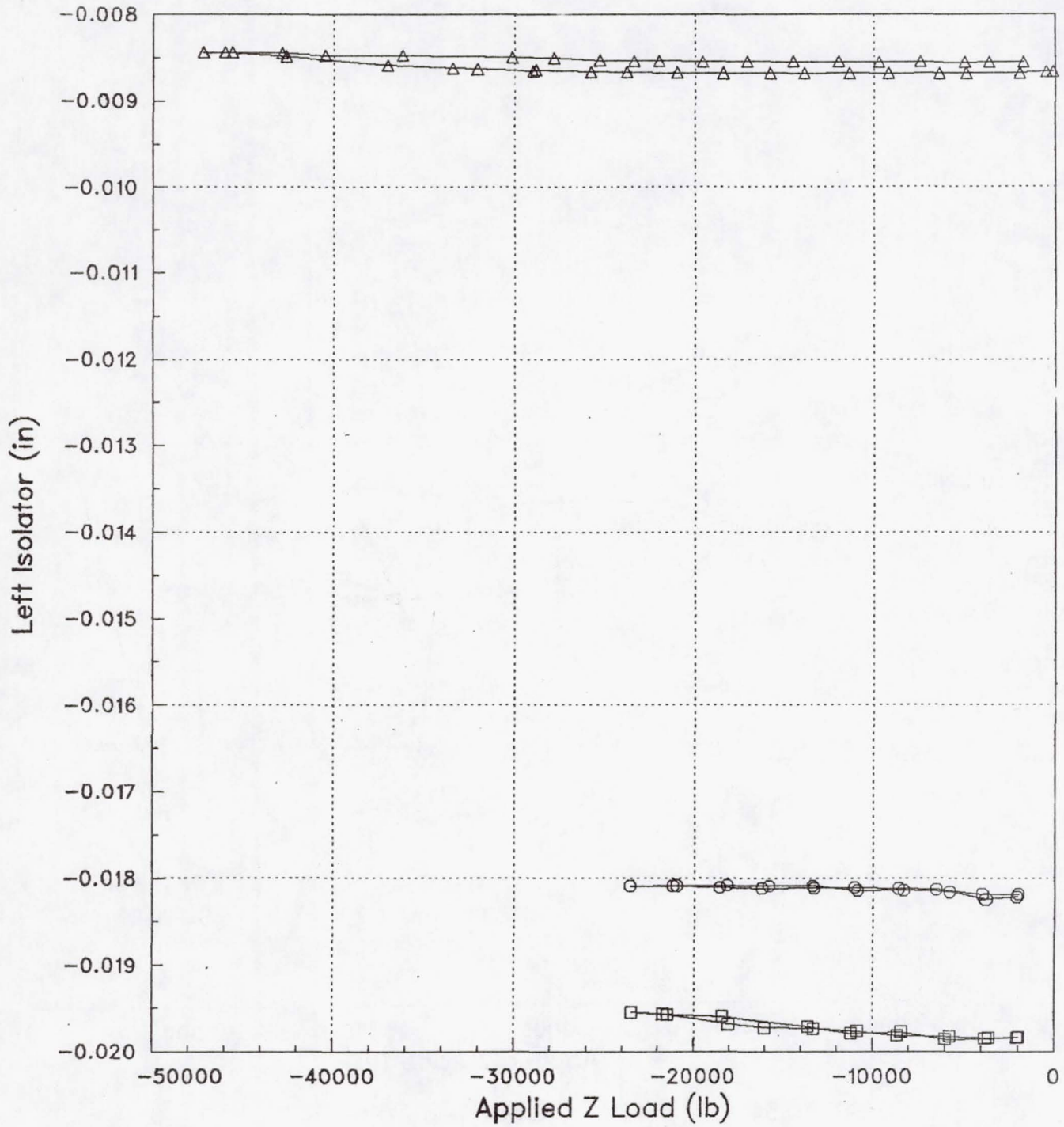
Applied Z Load
Constant Load: N



RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load

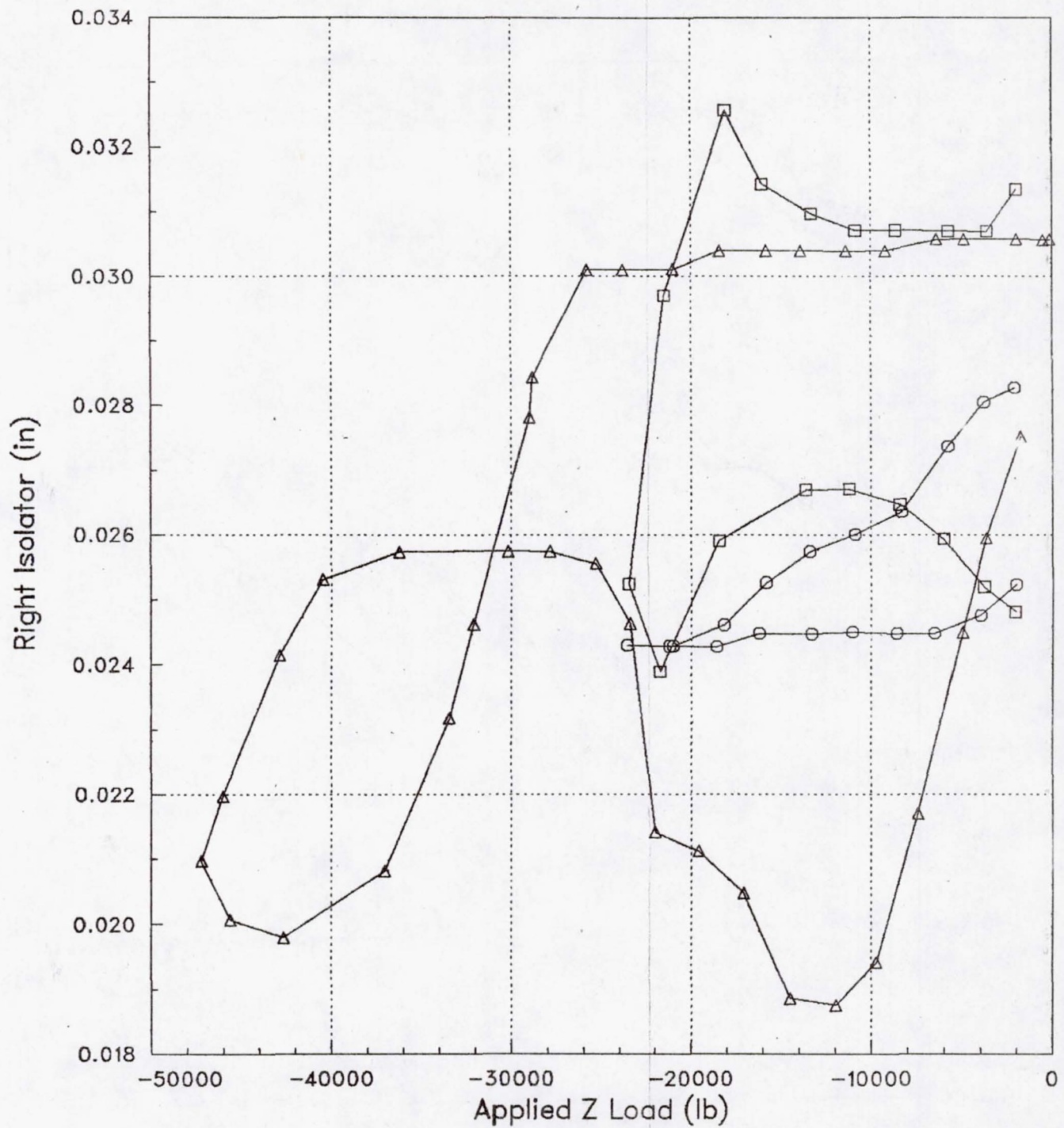
Constant Load: N



Runs: □ 34 ○ 44 △ 53

Applied Z Load

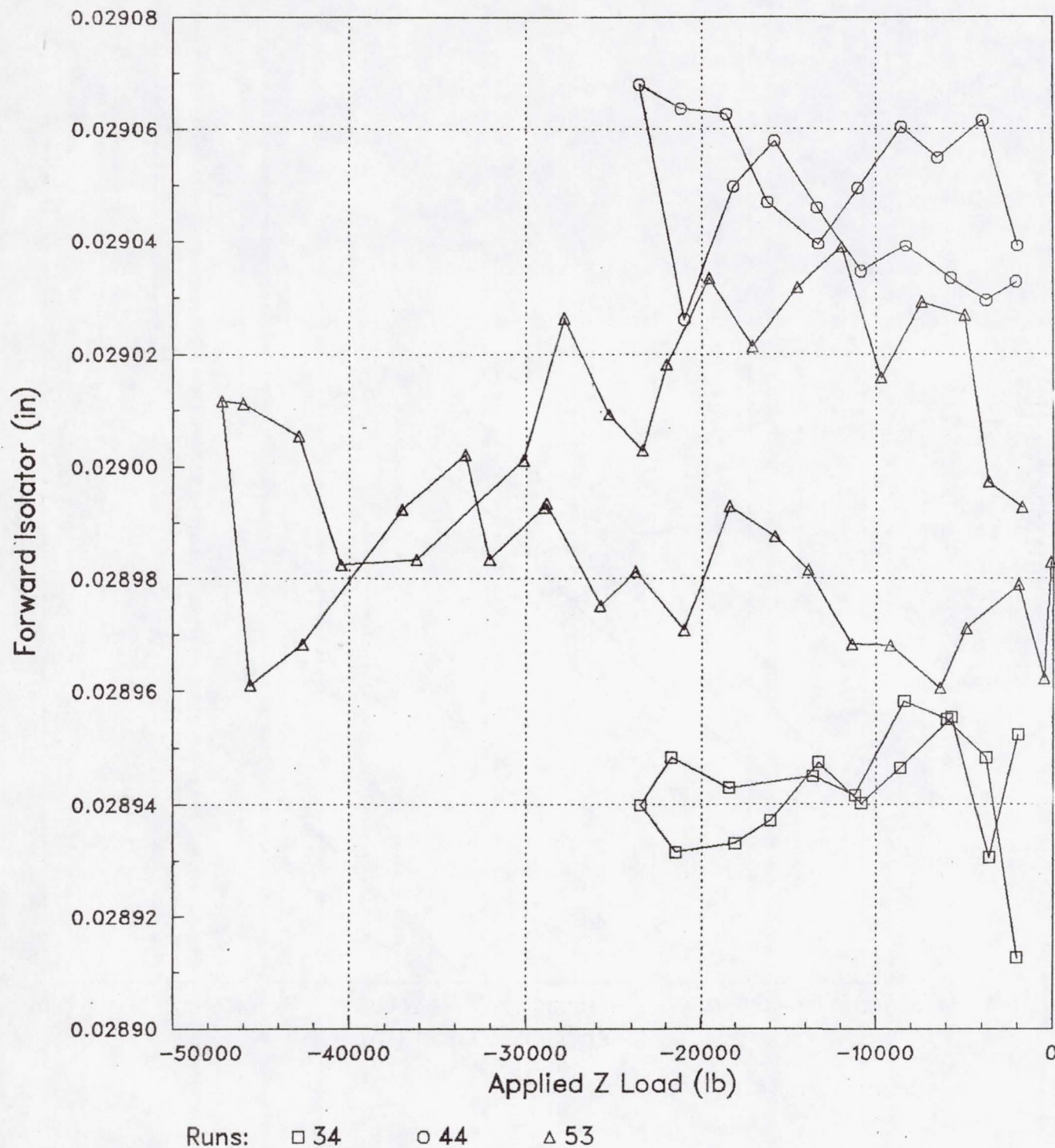
Constant Load: N



Runs: □ 34 ○ 44 △ 53

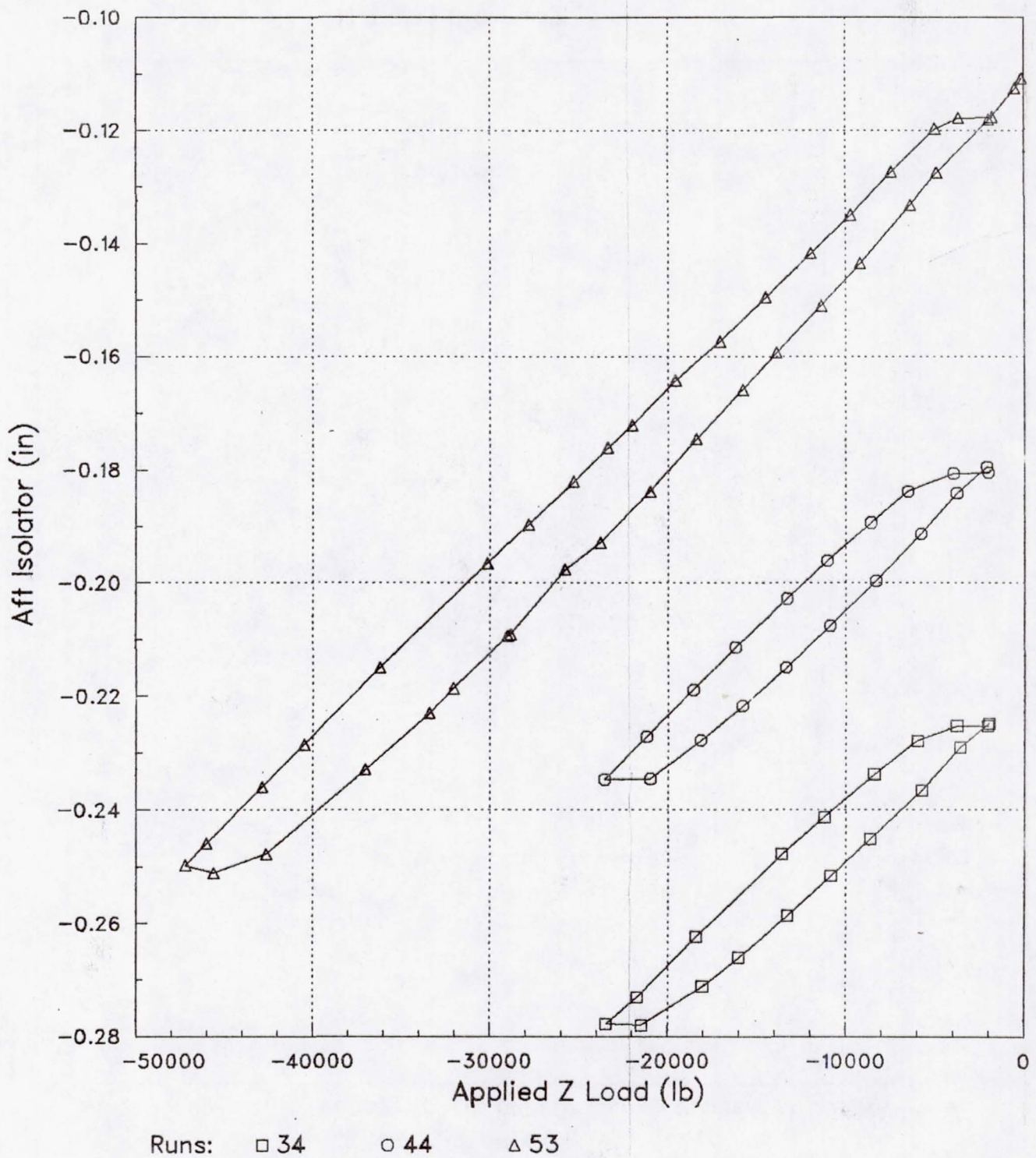
RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Load: N



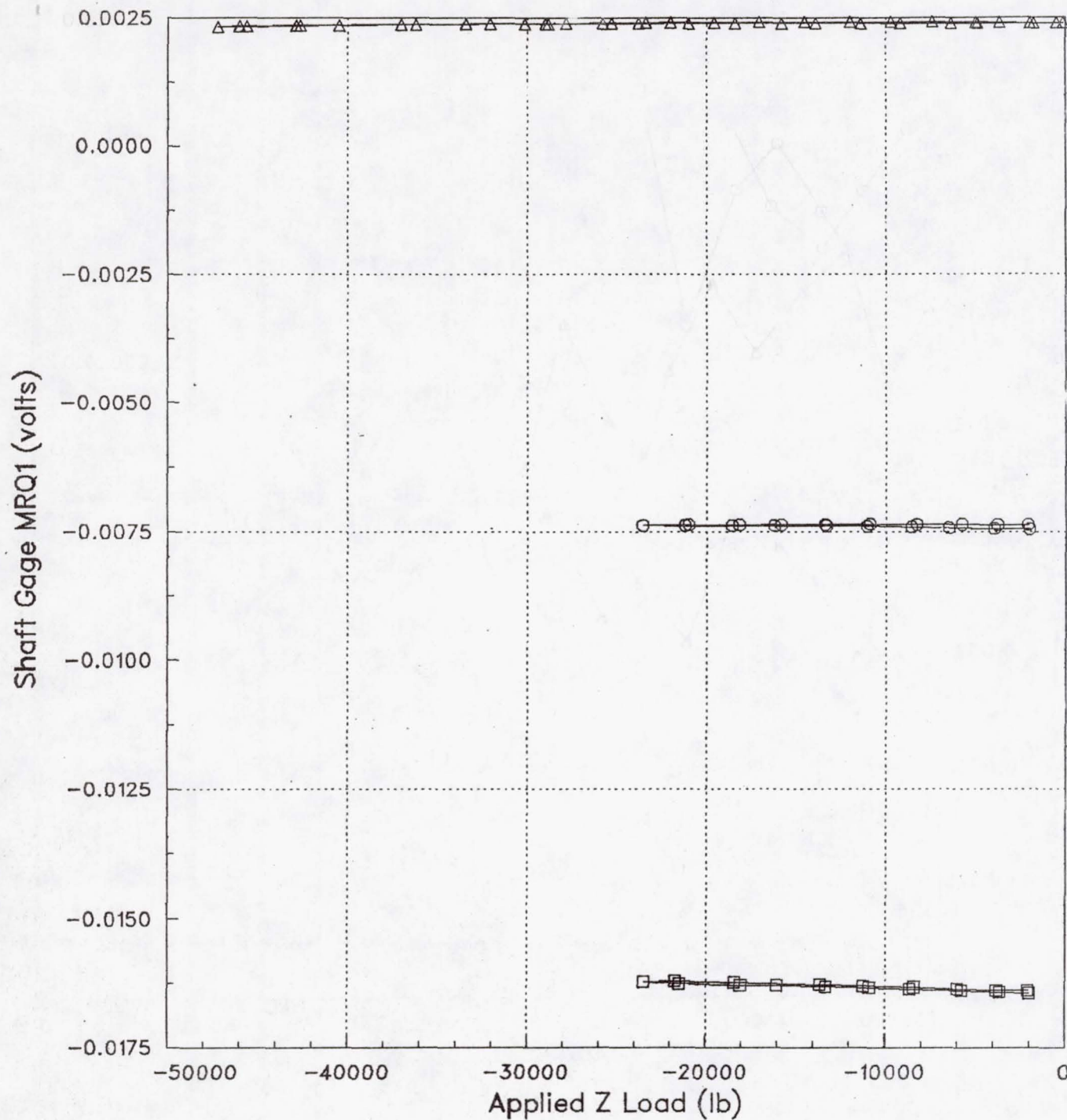
RSR 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Load: N



RSRA 741 1983 ROTOR CALIBRATION

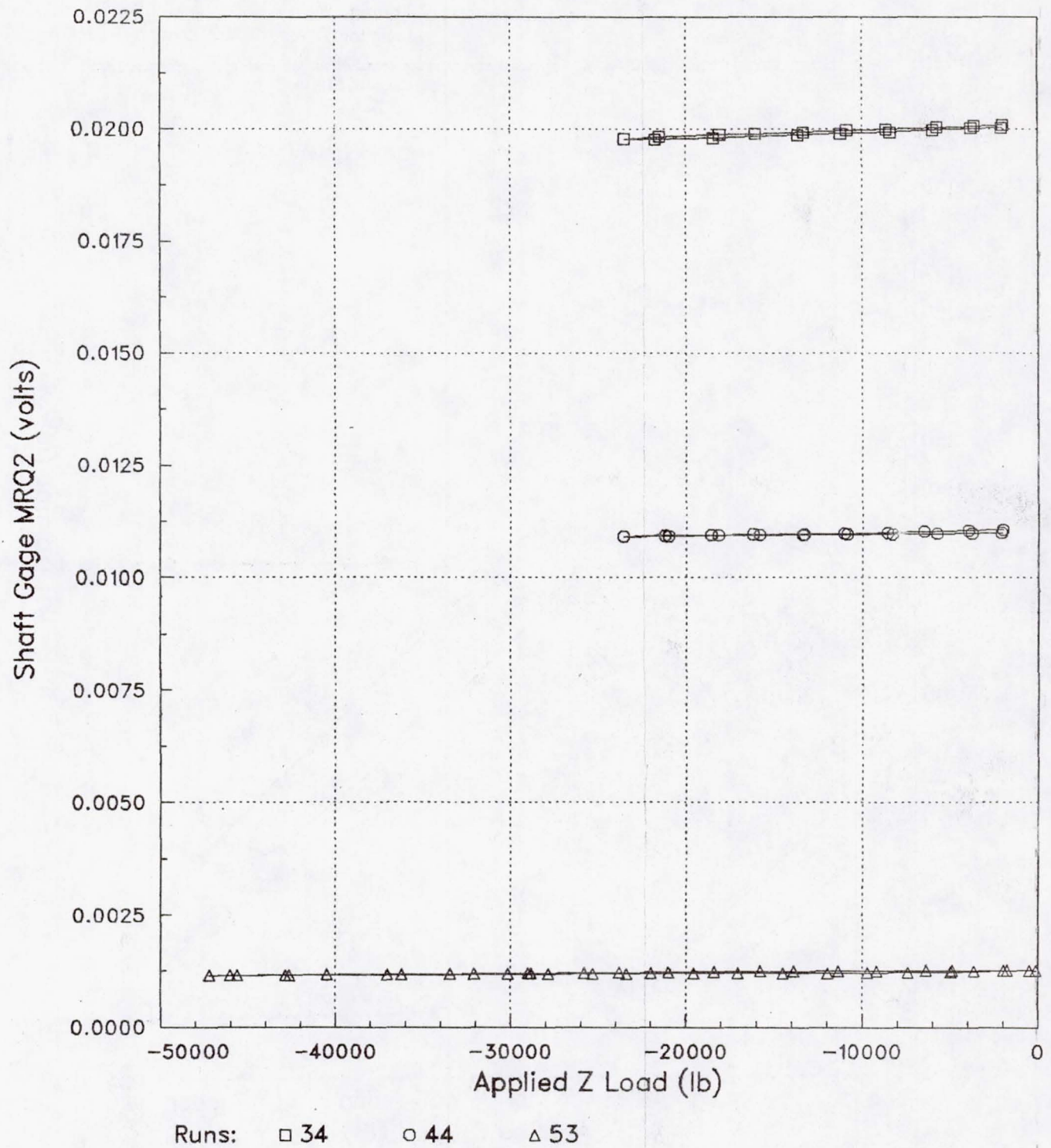
Applied Z Load
Constant Load: N



Runs: □ 34 ○ 44 △ 53

RSRA 741 1983 ROTOR CALIBRATION

Applied Z Load
Constant Load: N



REFERENCES

1. Burks, J. S.: Rotor Systems Research Aircraft (RSRA) Rotor Force and Moment Measurement System, AIAA Paper 81-2516, Nov. 1981.
2. Acree, C. W.: Performance of the Rotor Systems Research Aircraft Calibrated Rotor Loads Measurement System, presented at the AHS 38th Annual National Forum, Anaheim, California, May 1982.
3. Kuczynski, W. A.; and Madden, J.: The RSRA Active Isolation/Rotor Balance System, Paper No. 18, 4th European Rotorcraft and Powered Lift Aircraft Forum, Stresa, Italy, Sept. 1978.

1. Report No. NASA TM-84395		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle PRELIMINARY RESULTS OF THE FIRST STATIC CALIBRATION OF THE RSRA HELICOPTER ACTIVE-ISOLATOR ROTOR BALANCE SYSTEM				5. Report Date September 1983	
				6. Performing Organization Code	
7. Author(s) C. W. Acree, Jr.				8. Performing Organization Report No. A-9457	
9. Performing Organization Name and Address NASA Ames Research Center Moffett Field, Calif. 94035				10. Work Unit No. T-6564	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C., 20546				13. Type of Report and Period Covered Technical Memorandum	
				14. Sponsoring Agency Code 532-03-11	
15. Supplementary Notes Point of Contact: C. W. Acree, Jr., Ames Research Center, Moffett Field, Calif., 94035 (415) 969-6574 or FTS 448-6574					
16. Abstract The helicopter version of the Rotor Systems Research Aircraft (RSRA) is designed to make simultaneous measurements of all rotor forces and moments in flight in a manner analogous to a wind tunnel balance. Loads are measured by a combination of load cells, strain gages, and hydropneumatic active isolators which use pressure gages to measure loads. Complete evaluation of system performance required calibration of the rotor force- and moment-measuring system when installed in the aircraft. Measurement system responses to rotor loads obtained during the first static calibration of the RSRA helicopter are plotted and discussed here. Extensive plots of the raw transducer data are included in the Appendix.					
17. Key Words (Suggested by Author(s)) Rotor load measurement Helicopter static calibration Rotor systems research				18. Distribution Statement Unlimited Subject category: 05	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 260	
				22. Price* A12	